DATA PROCESSING

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Creating a comprehensive data processing system

By D. S. Greensmith

Recommendations based on experience of electronic data processing systems in the United States of America, several European countries and a number of companies in Great Britain

A story is current about a small, but expanding and prosperous company in the chemical industry. The company's two directors had both been most impressed with newspaper advertisements and reports about the fruits of research which were being gathered by some of the large companies. They decided that the time had come for their company to embark on a programme of fundamental research. An impressive laboratory was built, first-class equipment acquired, and in due course a suitably longhaired gentleman engaged to undertake the research programme. He reported one Monday morning and began work. As was their wont, the two directors met for coffee at mid-morning, and the conversation quickly got around to the new employee. "It is about time we went round to see how he's getting on," said one. "Good heavens, no," said the second, "Don't forget he's undertaking fundamental research. We mustn't rush things, you know . . . let's wait until lunchtime."

Most of us these days understand that the fruits of research are slow to mature; unfortunately we are not nearly so tolerant with regard to waiting to gain experience before the benefits of electronic data processing are obtained.

A great deal of interesting comment has emerged from individuals and in publications in the United States of America. Claims in terms of achievement have been modest, and there have been numerous admissions from progressive companies of fundamental mistakes in the very conception of many commercial data processing systems. It is my opinion that the lesson of these admissions has not been adequately learned in this country. The very same mistakes are being repeated, and perhaps because, based on the American admissions, we ought to have known better, we are very loth in this country to admit our mistakes.

Theoretically the development and application of electronic data processing is a natural for this country. To achieve success demands the harnessing of skills, managerial and technical, which we boast we possess; natural resources are not required. It would seem important, therefore, in our national interest that we should not only develop data processing equipment second to none, but that we should demonstrate that our commercial application also is without equal.

In dealing with the creation of a comprehensive data processing system I shall inevitably quote experience gained inside my own company. I have, however, also had experience of electronic data processing systems in the United States of America, several European countries

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Mr. D. S. Greensmith is general office manager of Boots Pure Drug Company Ltd.

and in a number of other companies in this country. My views, therefore, represent a blend of domestic and overseas experience.

Perhaps the operative word in the title is the first—"creating." It would seem that so far we have been far too preoccupied with the mere techniques of the subject and the hardware, and too little concerned with fixing worth-while management objectives and then working towards their achievement. It is essential if we are to reap the real potential rewards that our data processing systems should be designed against a much broader backcloth—a new conception of the office function and its place in the company structure. An office can only be really efficient if it helps forward the business of the company it serves. Too little thought appears to have been given to this essential concept, a concept which must inevitably condition our thinking about organization, methods and, of course, the data processing system best suited to an individual company's needs.

The history of most offices follows a well-established national pattern. They were originally staffed by book-keepers, and subsequently were taken over and developed by accountants. The prime purposes for which an office exists are:—

To keep the books of account and from these to produce annual accounts.

To control credit, cash, stocks and capital; reduce errors to a minimum, minimize the possibility of fraud, and where these occur to detect them as quickly as possible.

To build up financial records from statistics based on the accounting data.

Inland Revenue considerations have deflected the staff's attention to an abnormal degree, of necessity.

The functions set out above are still fundamental, but modern business conditions demand a wider service. Executive officers and senior management responsible for the promotion and control of the business must have pertinent, timely, and preferably selective information to facilitate their decision making. This of course is not new, but there is an excellent case for going even further and for asking suitably qualified office personnel to assist in the interpretation of data. New statistical and mathematical techniques can make a potent contribution. The office should be capable of producing economic reviews and data for forecasts. Arbitrary criteria will give way to statistically produced performance criteria. As a result, suppositions and assumptions will be superseded in large measure in favour of mathematical projections of past facts. Bias should influence decisions less. Management will not be expected to review a multitude of unrelated and disconnected reports. The office should in fact act in an advisory capacity rather than as a mere agency for producing vast quantities of undigested and uncorrelated figures.

It is my belief that any commercial data processing system should be conceived against an objective of this type. First we decide what we expect of the office and then we consider what data processing organization will help us achieve our aims. In the last few years the scientist has presented us with a wonderful range of new machinery which has now been adapted for office needs, and the possibility of achieving the sort of office I have in mind has been brought one step, one very long step, nearer.

Who creates the system?

If the argument thus far is accepted, it will certainly add weight to a point that has been made not infrequently in the past. Immense care should be taken in selecting the team to carry out the preliminary survey or feasibility study, and essentially the team should have access to, or preferably be responsible to, an individual at Board level. Many companies are in fact proceeding with lesser objectives than they should be, for the simple reason that the investigating team has either not sufficient status or has been composed of individuals who think on restricted departmental lines. Such a team will tend to justify the lesser objective, maybe realizing that there are wider horizons, but feeling that the organizational barriers are too strong to be broken down at the outset.

It is unlikely, if unfortunate, that many investigating teams will be given precise instructions as to the type of office organization which they are to consider. The terms of reference are frequently as vague as "To consider the possible application of electronic data processing to Company X." The management concerned are not recognizing their full responsibilities when this happens, but in such circumstances the team should take the initiative and make recommendations about the organization in the feasibility report, if only provisional ones. Planning should be as complete as possible before any order is placed for the equipment. It is, of course, impossible in an article of this nature, which is not intended to deal with any one company, to be dogmatic about organization. Even so, there are certain principles which I believe are worthy of serious consideration. They are:—

(1) The creation of a centralized Data Processing Unit or Units, standing in a service department relationship with the accounting and other functional departments. The production of figures, just as the production of goods or materials, should be a separate line management function.

(2) The creation of a Statistical Department charged with distributing figures produced by the Data Processing Units. A case can be made for linking the Operations Research Unit—if it exists—with this department.

(3) The creation of a centralized Data Processing Unit as envisaged under (1) will almost certainly throw up the possibility of merging existing accounting and recording functions. The fact that the basic paper work is performed in one place makes this possible, and may well result in some functions being eliminated entirely.

(4) Careful thought will have to be given to the internal audit function and its place in the structure.

(5) The head of the Data Processing Unit, even if the department is small at the outset, should be a person of stature. Inevitably if the process of centralization is continued the Data Processing Manager will control a most important function.

Theory versus practice

If now we examine what has happened in practice we find that few computer installations have been conceived with these broad objectives in mind. In many companies, for example, payroll has been chosen as the first task for conversion. Much has been written in the past few months about the weakness of using a computer for payroll, and it seems appropriate to examine the validity of the criticisms. There is certainly a growing body of experience which indicates that if we merely employ a computer with its subsidiary equipment to mechanize an individual task, then it is unlikely that the economies will justify the investment. The possibility of marginal savings in an installation of this type depends upon the efficiency of the system before conversion. However true this may be, it is not my intention to suggest that an electronic data processing system should never be employed on payroll. Although admittedly the possibilities are not so great as in other fields, payroll can be integrated with other tasks, cost analysis being the obvious example. If a payroll application is converted with these wider possibilities in mind, then experience suggests that there is a much greater chance that it can be justified.

It is almost certain that a detailed study of the data flow in any company or organization will lead to the conclusion that tasks other than payroll lend themselves more efficiently to integration, and in consequence to the establishment of a comprehensive system. Payroll, even though integrated with costing, can only be expected to produce results in terms of savings and possibly earlier figures. Other applications, if wisely planned, may on the other hand yield earnings in the shape of, say, reduced stock investment, or perhaps increased discounts in return for the earlier settlement of purchase accounts.

Another factor to bear in mind in creating the comprehensive or integrated system is the increasing part that well-established office machinery, specially adapted, can play. As an example, cash registers with punched tape attachments are in use in the United States for point-of-sale recording. In a retail organization data captured in this way on conventional machinery can be used over and over again in the integrated pattern to produce:—

Sales analyses
Cash control figures
Retail supplies requirements
Production and buying programmes
And a range of other data.

A particularly important recent development now available in Great Britain is the accounting machine with either punched card or punched tape attachment. Translation equipment can also be obtained to convert punched tape into punched cards. Many advantages are being claimed for this particular equipment, which can be programmed to carry out automatically the data translation needed for any subsequent system. Conventional records are, of course, produced simultaneously which obviates the need for check punching as the punched input can be verified from the copy records. At least two large companies in this country have already planned major installations employing these machines for sales accounting. The sales ledgers are posted in the accepted manner using the accounting machine, while the by-product punched information is processed by computer or calculator to build up sales analysis statistics.

One of the main intentions of the argument thus far has been to establish that while it may be necessary to start in a small way, such a step should only be taken if it has been conceived against a comprehensive plan. A plan must always be flexible, and flexibility is particularly important at this early stage in the development of commercial electronic data processing. New and improved hardware is being announced with alarming regularity, and it may well be that new equipment can result in a reappraisal of the problem. Experience too shows that some of the early claims made for equipment were over-optimistic and this fact is resulting in re-planning.

Retail organizations

As an example of this, consider retail organizations. Reference was made earlier to point-of-sale recording on specially designed cash registers. Retail companies in this country, in various European countries and in the U.S.A. that have embarked on electronic data processing programmes have been almost unanimous in thinking that point-of-sale recording represented the ultimate in planning. The early experience has not been encouraging. In some cases the equipment has been unreliable, selling has been slowed up in others, while a third group report that retail assistants under the stress of sales pressure produce on average about 5 per cent inaccuracy in the initial input data. As a result of this experience, ambitious plans are being abandoned. It may well be that a radical rethinking of the problem is necessary or that more conventional methods with lesser objectives are the right answer.

A methods team charged with creating a commercial data processing system based on a feasibility study will always tend to be pre-occupied with the day-to-day problems which abound. But if we are to achieve our ultimate goal, a truly efficient office, forward thinking and planning are essential, particularly at this stage in the development of hardware. This is not something which can be left to chance; time must be allotted for the purpose. In a large company it may even be worth while deputing a small specialist team to undertake this work. A number of machine companies have created special departments for this very purpose. Research financed by companies other than machine companies is another subject worthy of consideration. On two occasions in the past two years my own company's planning has been held up owing to the inadequacy or non-existence of hardware for particular purposes. In each case appropriate research has been financed, on the first occasion with a university department and on the second with a recognized machine company.

Decision making

Again quoting from my own company's experience, when our feasibility report had been accepted and the detailed study was starting, we took a decision which I believe has been of considerable importance to us subsequently. At that early stage we appointed senior programming and processing personnel, and ensured that they were consulted when all major methods decisions were being taken.

The creation of a comprehensive system will naturally demand wider consultation than is normal with methods work. Representatives of all management functions whose work is affected must obviously be consulted at each stage. This can become a ponderous and heartbreaking business. The process has been facilitated in our case by the establishment of a committee of reference which has met only as required, with a director or senior executive officer in the chair. It is perhaps important to add that the directors and senior executives concerned are knowledgeable about electronic data processing. A high proportion attended the first company appreciation course that was held, and those intimately involved have kept closely in touch with developments both inside and outside the company.

Preparing for the changeover

Widely differing figures are quoted when one talks with companies as to the time taken in changing over to an electronic data processing system. To some extent the time taken depends upon the degree to which the computer and ancillary equipment have been proved in practice. While there may be exceptions, a much quicker changeover can be expected if one is employing, say, an IBM 650 system, of which many hundreds have been delivered and installed, than a system of which only a handful are in use. Hardware is not the only problem, however. Changeover time is bound to be long if one is grappling with both a complicated new machine and far-reaching methods changes at one and the same time. Wherever possible, I believe that important methods changes should be tried out, if only on a limited scale, before the electronic data processing system is actually installed and working. Time and effort spent in this way will almost certainly ease the burdens of introducing the computer.

Commercial practice

If now we examine what is happening in practice in this country, I doubt if we can find more than two or three examples of systems that can claim to be "comprehensive," bearing in mind the definition given. A controversial article in the *Financial Times* some months ago claimed that Western Europe was ahead of Britain in this respect. Certainly two electronic data processing installations which I have had the pleasure of seeing in Western Germany stand out in my mind as first-class examples. In each case a breadth of integration has been achieved and results obtained which are heartening, to say the least.

GROSSVERSANDHAUS QUELLE:—

This large and rapidly expanding mail-order house has its headquarters at Fürth, just outside Nuremberg.

A completely integrated ordering-recording warehouse and despatch system has been conceived which employs a special-purpose computer built by Standard Elektrik, of Stuttgart, at a cost exceeding £250,000.

The computer maintains in its memory a perpetual inventory of 18,500 items of merchandise.

Orders quoting article codes made out by customers are handled by approximately 50 order girls. Each girl is positioned at a desk into which is built a special keyboard and other equipment capable of addressing the computer direct.

The computer confirms availability of stock, looks up the price and extends price times quantity, reduces theoretical stock and prints out merchandise slips for use in the warehouse. The merchandise slips which are the key to the whole warehouse operation are routed to stock rooms. Complete synchronization has been achieved so that the various items for an order collect at a single packing station.

A special type of keyboard machine has been devised such that the computer can be requested to give the quantity of stock held of any individual item immediately.

Warehouse receipts are advised to the computer immediately.

Buyers are supplied with appropriate stock figures every 48 hours.

Programmes have been devised to extract information regarding special fluctuations, etc.

The computer is being enlarged to handle credit accounting procedures.

The following results are claimed consequent upon the introduction of this integrated system:–

Paper work and checking reduced.

Physical stocktaking is only carried out once per annum.

The number of warehouse and office staff required to handle orders has been reduced by more than 50 per cent.

Warehouse stock investment has been reduced by approximately 20 per cent.

Service to customers has been improved.

KAUFHALLE, G.M.b.H.:—

The second example is that of a chain-store organization with headquarters in Cologne.

In this case a general-purpose Remington Rand Univac 120 and a wide range of punched card peripheral equipment are employed. Basic to the whole system is a master set of punched inventory cards. These are used in all accounting and statistical work for each of the 36 branches for stocktaking, sales and purchases. Complete integration of these tasks has been achieved.

An interesting feature of this installation is the very extensive use made of mark sensing.

Amongst the advantages claimed are:—

Clerical work reduced with appreciable staff saving.

High degree of accuracy achieved.

Stock and sales statistics are available much more quickly.

Increased discounts from suppliers as a result of payment on invoice within five days.

Management planning has been facilitated.

Most of the principles that have been advocated in this article have been observed by these two companies. In each case there is clear evidence of a new concept of data processing rather than an attempt to "hot-up" existing departmental systems.

Under present day competitive conditions our data processing requirements grow in complexity. The comprehensive system provides an answer. The challenge remains—can we create such a system?

Prediction by computer

By J. K. Wyatt B.Sc., F.S.S.

Management nowadays can have a really comprehensive quantitative basis for decision-taking. A mathematical model of the system to be investigated is set up and the effects of variations of relevant features determined by an electronic computer. It is thus possible to experiment without incurring the expense and upset of doing so in real life.

In this article Mr. Wyatt describes how the Glacier Metal Company, Ltd., investigated the problems associated with a new machine shop they wished to establish. Similar methods are applicable to commercial activities in general

Simulation, in the forms developed by Operational Research, can provide management with a quantitative basis for decision-making. A model of the system to be investigated is set up which imitates the relevant properties of the system as realistically as possible. This is not a physical model in the conventional sense, but consists of a series of equations that correlate all the various factors involved. This done, certain features are varied and the effects of these variations determined.

If the model is a good one, what is discovered by its use can be expected to occur in practice. Thus it is possible to learn something about how real-life systems behave without the risks and expense of actually trying them out.

An investigation of the above type was required at the Glacier Metal Company when it became necessary to study the characteristics of a machine shop which was not then in existence. The shop was being set up for the manufacture of items which had previously been made in a general machining department.

Certain information about the shop was known in advance. It was known, for instance, that it would contain initially about 30 machines and would be engaged on batch production work. It was also possible to specify in advance the machines needed in the manufacture of a particular part, the order in which they would be used, the times for setting-up the machines and the time involved in machining. Any number of machines, up to a maximum of 20, might be needed in the manufacture of any one part. Parts would not progress through the shop in a fixed direction because the machining operations required for one part might have to be performed in the reverse order on another.

The simulation was required to show the time it would take to produce particular batches of parts, the amount of work waiting at each machine, the utilization of labour and the totals of work in progress—all this under various conditions of loading work on the machine shop and with different numbers of men and machines.

Previously, simulations required by the company had been performed with pencil and paper. None of these had been of systems as complex as a machine shop, yet they had involved a great deal of monotonous and repetitive arithmetic. As a computer thrives on just this type of work, one was clearly needed, the only alternative being to simplify the model out of all recognition—indeed, to the extent that it would no longer accurately represent the situation.

The model created works in this way. Each job is allocated to the appropriate machines in the correct sequence. There are more machines in the workshop than there are men to operate them. Jobs wait in a queue at each machine and are dealt with on a "first-come, first-served" basis. When the job reaches the head of the queue further time elapses during which the machine is set up to perform the work; the parts are then processed.

Every time a man completes the processing of a job on a particular machine, a priority rule determines whether he should start on the next job waiting in the queue or move to another machine. Two-shift working is incorporated; the machines which gain or lose men at each change of shift are decided by the priority rule.

Mr. J. K. Wyatt is in the Operations Research Department of the Glacier Metal Co., Ltd.

The manner in which the computer is used to simulate the operation of the machine shop will probably be clear if a simplified example is described. Consider a machine shop with six machines and three operators. The accompanying tables show the times at which jobs are scheduled to be completed on the machines. Times are measured from the moment when the simulation started and are quoted as integral numbers, where the unit of time is one-hundredth of an hour.

First, the computer is set to examine the jobs waiting at the heads of all the queues in order to locate the job that will be completed first. In the case shown, machine C will be chosen first because 13,049 is the smallest number in column 1. The action now taken by the computer is, in effect, to move forward through time until it reaches the moment quoted, i.e. 13,049 units of time. This, of course, means that the operation on machine C will have been completed and so the job processed on this machine is transferred to the end of the queue of the next machine specified in the production sequence. This, say, is machine F and the job enters the third position in the queue. Suppose the time required to complete the particular operation on this machine is 542 units; then the new completion time for this job is derived by adding 542 to the completion time given for the job immediately before it in the queue. The new completion time therefore becomes 13,901 + 542 = 14,443. This figure is seen in the second table. The queue of work on machine C is now moved forward, the number 13,627 coming to the head of the queue.

Only three operators are available to work the six machines; three machines must, therefore, be idle. Obviously, when the computer is scanning column 1 to detect the lowest number,

		Position in the Queue				
		1	2	3	4	5
MACHINE	A	2^{37}	2^{37}	2^{37}	2^{37}	2^{37}
	B	13,425	2^{37}	2^{37}	2^{37}	2^{37}
	C	13,049	13,627	14,308	2^{37}	2^{37}
	D	$2^{37}+13,290$	$2^{37}+13,543$	2^{37}	2^{37}	2^{37}
	E	2^{37}	2^{37}	2^{37}	2^{37}	2^{37}
	F	13,614	13,901	2^{37}	2^{37}	2^{37}

		Position in the Queue				
		1	2	3	4	5
MACHINE	A	2^{37}	2^{37}	2^{37}	2^{37}	2^{37}
	B	13,425	2^{37}	2^{37}	2^{37}	2^{37}
	C	13,627	14,308	2^{37}	2^{37}	2^{37}
	D	$2^{37}+13,726$	$2^{37}+13,979$	2^{37}	2^{37}	2^{37}
	E	2^{37}	2^{37}	2^{37}	2^{37}	2^{37}
	F	13,614	13,901	14,443	2^{37}	2^{37}

it must be prevented from choosing a machine that is not manned. This is done by adding a very large number, 2^{37}, to the completion times of all jobs on unmanned machines. This number also appears in all positions in the queues not occupied by jobs. In this way it is possible to make the computer ignore all machines having no work (machines A and E) and also unmanned machines (machine D).

If the computer moved forward 436 units of time to get to 13,049, then 436 units must be added to the completion times of all jobs waiting in the queues of unmanned machines. This has been done for the two jobs waiting at machine D and the new completion times are quoted in the second table. All is now ready for the process to be repeated. The computer will search column 1 for the earliest completion time and the procedure will be gone through again.

A system of priorities is necessary to determine how the men shall be allocated to the machines. In real life this is a matter of intuition, but because the computer is incapable of exercising this faculty, a rule had to be found that would appear reasonable to workshop supervisors and be capable of being programmed.* The obvious rule of allocating men to the machines with the longest queues would penalize those jobs going on lightly loaded machines. The solution adopted therefore is to set a criterion of priority for each job by assessing the difference between the scheduled completion time for the job on its current machine and the time it joined the queue for that machine.

Whenever a job is completed on a machine the operator is sent to a central reserve. The computer then scans the jobs at the heads of the queues of the unmanned machines and allocates the man to the machine with the job possessing the highest priority on the basis just quoted. Of course, the machine the operator has just left has become inactive and, if it still has a queue of work, it will often reclaim him. In this event, no break occurs in the operation of the particular machine because the computer does not move forward in time while it performs the allocation procedure.

In order that one programme routine may be able to cope with the arrival of jobs at the machine shop as well as with movements from machine to machine, two special "arrival machines" are included in the model of the situation. Each arrival machine has room for a queue of 48 jobs. If 96 jobs are placed in the queues of these machines the normal programme procedure will see to it that they are fed into the workshop at the right times. A continuous flow of work is maintained by repeatedly feeding in a fixed sequence of jobs.

A Ferranti Pegasus computer is used to perform the machine shop simulation. The data which need to accompany a job on its tour of the machine shop can be contained in two registers of the Pegasus information store. Consequently, to provide sufficient information storage capacity for 48 separate jobs to be held in a queue, 96 consecutive registers are earmarked. (The number 48 has no particular virtue: it is dictated primarily by the storage capacity available within the computer.) A maximum number of 40 machines is envisaged for the workshop, so 3,840 registers are needed to hold their queues. Data which do not need to accompany the job on the journey from machine to machine are recorded in another part of the information store. Examples of such data are the reference numbers of the machines needed for the complete manufacturing cycle, arranged in sequence, together with the preparation times for each operation and the machining times.

The two tables opposite illustrate the type of data recorded in the first register. The second register contains the priority value allocated to each job, the job number and the number of machines that the job has visited. Without this last information it would not be possible to look up the details of the next operation to be performed.

Shift working

The simulation of the machine shop incorporates a means of periodically increasing and decreasing the number of men working in the shop. In this way shift working can be simulated. Both the length of the shifts and the distribution of manpower can be varied. Extra men are added to the reserve of free men on changing from night shift to day shift. These men are then allocated to machines, in accordance with the priority system already described, until either no more men are free or all machines with queues of work have received men. Conversely, the change from day shift to night shift involves, first, the removal of men from the reserve of free men; then, if further men have to go, they are removed, one by one, from the active machines with the lowest priority jobs.

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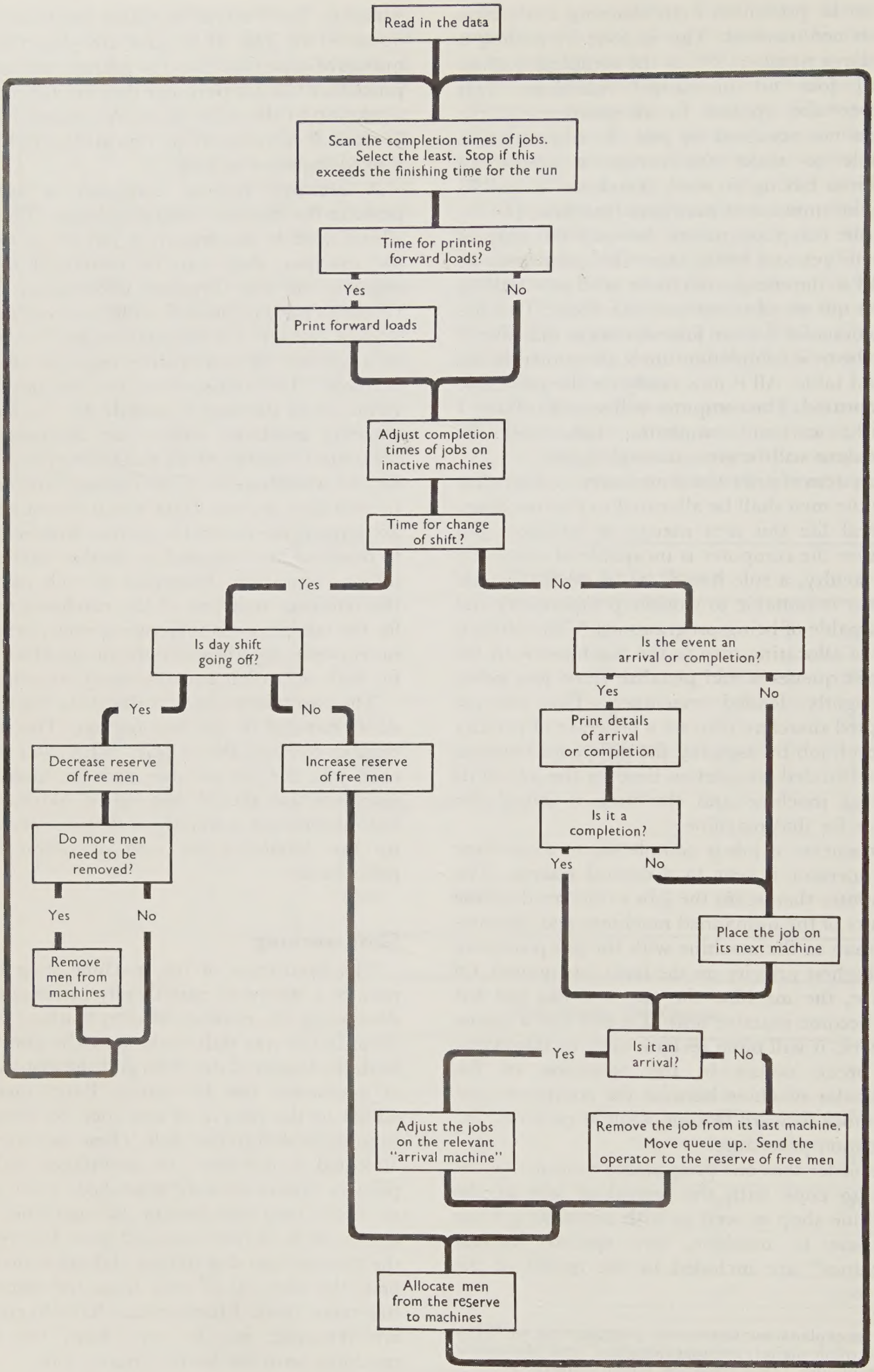
*For an explanation of computer programming see "How an electronic digital computer calculates" and "Automatic Programming," *Data Processing*, January-March, 1959.


Read in the data
Scan the completion times of jobs. Select the least. Stop if this exceeds the finishing time for the run
Time for printing forward loads?
Yes
No
Print forward loads
Adjust completion times of jobs on inactive machines
Time for change of shift?
Yes
No
Is day shift going off?
Yes
No
Decrease reserve of free men
Increase reserve of free men
Do more men need to be removed?
Yes
No
Remove men from machines
Is the event an arrival or completion?
Yes
No
Print details of arrival or completion
Is it a completion?
Yes
No
Place the job on its next machine
Is it an arrival?
Yes
No
Adjust the jobs on the relevant "arrival machine"
Remove the job from its last machine. Move queue up. Send the operator to the reserve of free men
Allocate men from the reserve to machines

Every time the computer performs an action, a test is made to see whether it is time to print a report on the queues of work at each machine. These reports show the forward load for each machine, that is the completion time of the final job in the queue minus the present time.

A simplified flow chart showing the main features of the programme appears opposite.

The computer performs this cycle of operations approximately once per second. It can be seen that during a run most of the programme is used repeatedly. Those parts which are used once only are concerned with the introduction of data at the start of a run or with stopping the computer when either a job is about to be loaded on to a machine that already has 48 jobs in its queue or a certain length of time has been simulated, for example, 2,000 working hours. Incidentally, the computer can simulate 10 hours' operation of the machine shop in one minute.

Writing the programme

The writing of the programme was facilitated by the fact that it could be broken down quite naturally into its component parts. These parts correspond roughly with the blocks of the diagram. Attention was then concentrated on one part at a time. Each part required a programme whose length was of the order of 50 instructions. These small programmes, known as subroutines, were thoroughly tested using fictitious data. After testing, each was preserved in the form of a length of punched paper tape known to be correct.

When all the subroutines had been written and tested they were assembled together and the complete programme was ready for testing. This simple linking together of the subroutine tapes was made possible by the Pegasus facility of assembly which eliminates the need to make changes in the subroutines when they are to be held in a part of the computer store different from that envisaged when they were being written.

The assembled programme was tested using fictitious data relating to a 300-hour period of operation of a machine shop, containing three machines, into which four jobs were fed repeatedly. The results obtained were compared with two sets of results worked out by hand by two persons independently—the difficulty at this stage was to make these two pencil-and-paper computations agree. It should be mentioned that programmes are seldom correct in the form in which they are written initially and several short runs on the computer are necessary to eliminate errors. In computer circles this is known as "debugging" the programme.

The sequence of events during a typical run on Pegasus is this: first, the programme is read from paper tape and recorded in the main store of the computer—a magnetic drum. Then the data relating to a particular run are read from punched paper tape and stored on the drum. At this point the output punch starts to work and continues recording the results intermittently with intervals for computation. The paper tape which it produces is fed into a teleprinter that prints the results.

On the final document appear job arrival and completion times and periodic statements of the forward load situation on each machine. Further items which may be included later are reports on manpower utilization and work in progress. If the output punch is working for about 30 per cent of the time, the teleprinter will not lag far behind in printing the results. The run is normally stopped by hand.

Certain storage registers in the computer may be observed by means of a monitor tube during the actual run. It has been found instructive to watch fluctuations in the reserve of free men in this way. After a run, a change in the number of men or the numbers and types of machine may be made before the next run in the hope of eliminating such faults as production bottlenecks and poor utilization of labour.

As yet, no attempt has been made to decide the best sequence for feeding jobs into the machine shop. If this were the object of the exercise, a similar model would be set up and the jobs fed into the shop in various orders. It would not be possible to consider all permutations unless the number of jobs involved was very small. Even the speed of an electronic computer is quite inadequate for the astronomical number of different sequences in which 50 jobs, for example, can be arranged. Although the true optimum may not be attainable, a good approximation can be derived by considering a small fraction of all possible permutations. This technique is being used in the United States by the General Electric Company, where it has been found that even their IBM 701 computer has limitations of speed. If any doubts exist as to the necessity of developing bigger and faster computers, then simulation and production scheduling can be quoted as fields in which the potentialities of such machines could always be exploited to the full.

Visual data instantaneously

Ingenious versatile closed-circuit television system that dispenses with the cost and complication of a television camera

An inexpensive television communication system has been developed by Decca Radar Limited. Information written on a glass panel, or picture transparencies, can be transmitted to any number of receivers instantaneously. Limited editing facilities enable data received from one source to be modified before being re-transmitted.

An installation and its use by a stockbroking firm is described, also an experimental application by British Railways. In both cases the equipment replaces the telephone to provide a more efficient and rapid means of communication

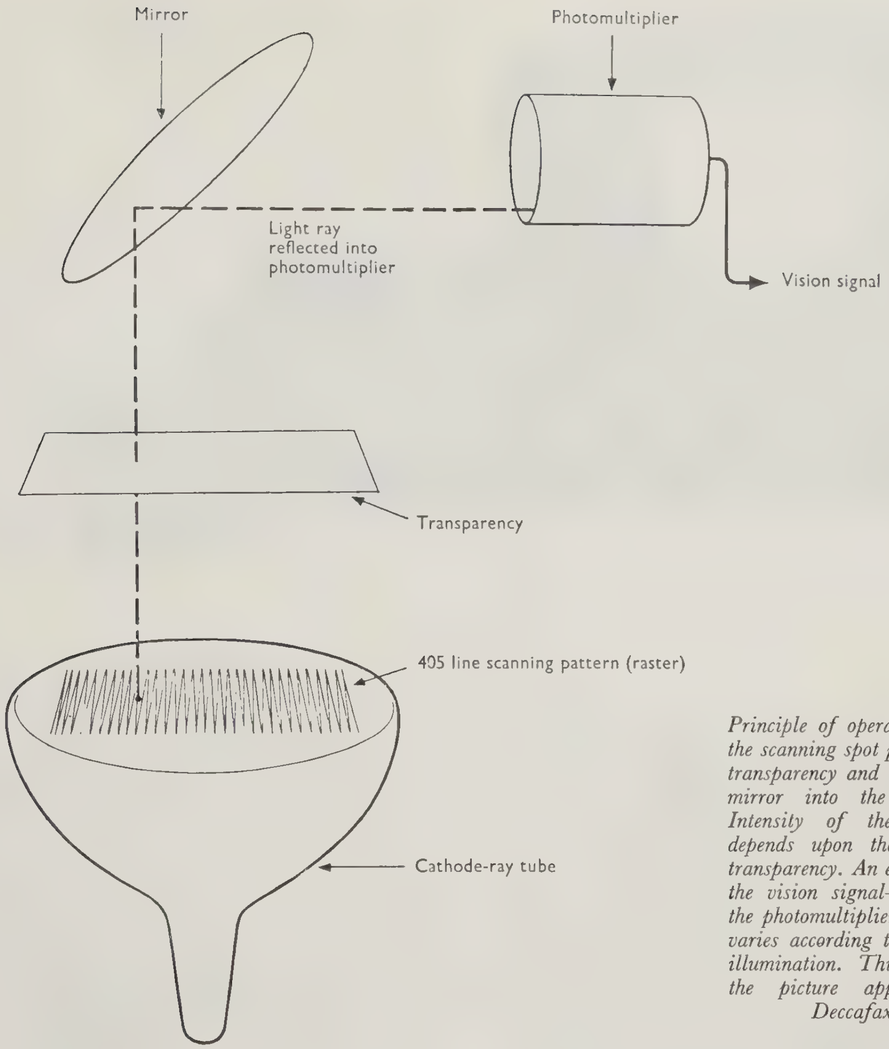
Although for years it has been possible to transmit visual information instantaneously by closed-circuit television, no great use of this equipment has been made. Undoubtedly, the high initial cost has been a deterrent. However, by ingenious design, Decca Radar Limited have overcome this problem and now manufacture a facsimile transmitting system that, in effect, is a closed-television circuit without the television camera—the item that normally is the most expensive single piece of equipment. In addition, the Decca system permits visual information, transmitted from one point, to be edited before it is re-transmitted to its final destination. This operational flexibility is obtained without increased technical complexity or cost.

In its simplest form, the system, which is called Deccafax, consists of a transmitter connected by a landline to a receiver. These two units may be situated up to 2,000 yards apart. If it is required to transmit over greater distances amplifiers to boost the signal are fitted at intervals of 1,200 to 1,500 yards. Twelve miles is the greatest distance over which a picture has been transmitted.

Theoretically there is no upper limit, but because the coaxial cable used for the landline costs £528 a mile, and this figure does not include laying the cable or the provision of amplifiers, a practical limit is imposed by price.

The simpler of the two Deccafax units is the receiver. This is fitted with a special 14-inch cathode-ray tube that gives an almost flicker-free picture. A 405-line picture is displayed to

The Deccafax transmitter receiver unit is fitted with a 14-inch cathode-ray tube and costs £290


Mirror
Photomultiplier
Light ray reflected into photomultiplier
Vision signal
Transparency
405 line scanning pattern (raster)
Cathode-ray tube

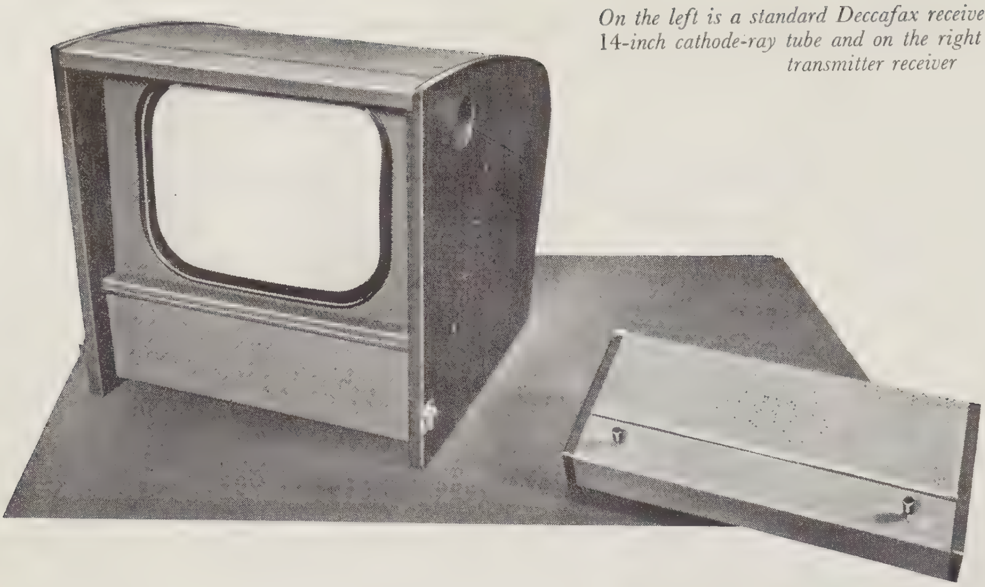
Principle of operation. Light from the scanning spot passes through the transparency and is reflected by the mirror into the photomultiplier. Intensity of the light received depends upon the design on the transparency. An electrical signal—the vision signal—is produced by the photomultiplier and its strength varies according to the intensity of illumination. This signal controls the picture appearing on the Deccafax receiver

conform with standard British television practice. Two manual controls are provided, by which the brightness and height of the picture can be altered. A third control is the on-off switch.

The transmitter is similar to the receiver with the addition of a hood, in the top of which is fitted an electronic device called a photomultiplier tube. A photomultiplier is a photoelectric cell that is extremely sensitive to variations in the intensity of illumination. It produces an electric current, the strength of which is a measure of the amount of light falling on the cell at that particular instant. Light from the screen of the cathode-ray tube is reflected by a mirror into the photomultiplier fitted in the hood. Dependent upon the picture projected, the luminosity of the light spot will vary as it traces out the 405 lines of the scanning pattern and the electrical signal produced by the photomultiplier will vary in sympathy.

After amplification, this electrical signal is sent to a receiver where it alters the intensity of the scanning spot projected on the cathode-ray tube, with the result that any picture placed in front of the screen of the transmitter will be reproduced immediately on the screen of the receiver. This is the relatively simple device which replaces the television camera. A Deccafax transmitter costs £290 in contrast with the £500 or £600 of a television camera.

Preparation of a picture for transmission is extremely simple. The limitations are that the latter should be a transparency and not exceed



On the left is a standard Deccafax receiver equipped with a 14-inch cathode-ray tube and on the right a two-way sound transmitter receiver

10 inches by 8 inches. When the transmitter unit is switched on, the uniform 405-line pattern traced out by the scanning spot (known as the raster) will appear on the screen of the cathode-ray tube. After the transparency is placed over the screen, the light from the scanning spot will be obscured where it passes behind opaque portions of the transparency. Consequently, as remarked earlier, the intensity of the light reflected into the photomultiplier will vary according to the design on the transparency and, in turn, the electrical signal produced by the photomultiplier will vary in an identical manner. When this electrical signal is supplied to a receiver, it will cause the design of the transparency to be faithfully reproduced on the screen.

As with the conventional domestic television sets, a clear glass cover is fitted in front of the cathode-ray tube for protection. Transparencies to be projected are laid on this cover. Where transparencies are not available, the cover can be used as a slate on which messages are written. A Chinagraph pencil is used. A facsimile of the written data will be reproduced at the receiver. After transmission, the Chinagraph marks can be rubbed off.

As far as the photomultiplier is concerned, any image will be transmitted to the receiver whether it appears on the screen of the cathode-ray tube or on a transparency placed immediately over the tube. It is this feature which enables visual information received from one source to be edited before it is passed to a final destination.

Visual data can be sent from one transmitter and reproduced on the screen of a second transmitter. In this instance, of course, the second transmitter is being used as a receiver. The picture appearing on the screen of the second transmitter can be re-transmitted, if required. Where the information is to be edited, this is done by marking the glass cover with a Chinagraph pencil, in the manner already described, or a transparency can be placed in position on the glass cover. The composite picture derived by this superimposition can then be transmitted to another receiver.

Naturally, the amount of editing that can be done is restricted to deletions—by obscuring parts of the picture projected on the screen—and additions by writing in new data. It is not possible to rearrange the sequence, or format, of the original data. Technically, it is possible to provide more versatile editing facilities, but for business applications it is extremely doubtful if the additional cost and complexity would be warranted.

Many types of Deccafax system can be constructed. Where two-way communication is required between two points, two transmitters are interconnected. The transmitters would then be used alternately as transmitters and receivers. A more usual practice is to link several transmitters to one system, together with a larger number of receivers. Obviously, a transmitter is located at every point where data are derived, and the receivers are situated where information only is required. Messages can be conveyed between any or all of the units within one system, depending upon the switching arrangements provided.

Other items of television equipment can be incorporated in a Deccafax system. Although a television camera is not needed, one can be connected where external views, or scenes, have to be transmitted. Also, conventional domestic television receivers can be modified to act as receivers. Sound equipment, too, may be linked with the Deccafax units to provide two-way aural as well as visual communication. Special sound units are built that fit on to the front of both transmitters and receivers. Sound units are interconnected by a separate landline.

A transmitter costs £290, a receiver £130, a sound transmitter receiver £30 and amplifiers, for boosting the vision signal in the landline, are £25 each. A basic two-way system for sending visual information therefore costs £600 to £650.

Initially, this equipment has been used in commerce to eliminate extensive numbers of telephone calls that were made to bring up-to-date information that, in general, did not change rapidly. A good example of this is provided by stockbroking. A leading firm of stockbrokers has installed an extensive Deccafax system. In their local office or "box" near the Stock Exchange are situated 10 transmitters. In their offices approximately a quarter of a mile away are six receivers. At the box, information

Deccafax transmitters located in a "box" near the Stock Exchange are used to transmit instantaneously information about current share prices to a number of commercial offices; some of them situated as far as one mile from the Exchange

received of the current prices of various stocks and shares is written on to prepared transparencies and is immediately available at the main office. A list of share prices for 48 companies can be provided on one transparency 10 inches by 8 inches.

As 10 transmitters are used, data concerning 480 shares can be provided simultaneously. Each receiver is fitted with a selection dial and the person viewing can choose which of the 10 transmissions he wishes to see. Each transmitter provides share information for one particular class of business. It is estimated that prices transmitted never lag behind the prices quoted on the floor of the Stock Exchange by more than four minutes.

In addition to providing information to their own head office, the stockbrokers also transmit the data to 24 customers. Each customer is provided with one or more receivers. The majority are situated within a short distance of the Stock Exchange. The most remote receiver is just over one mile away.

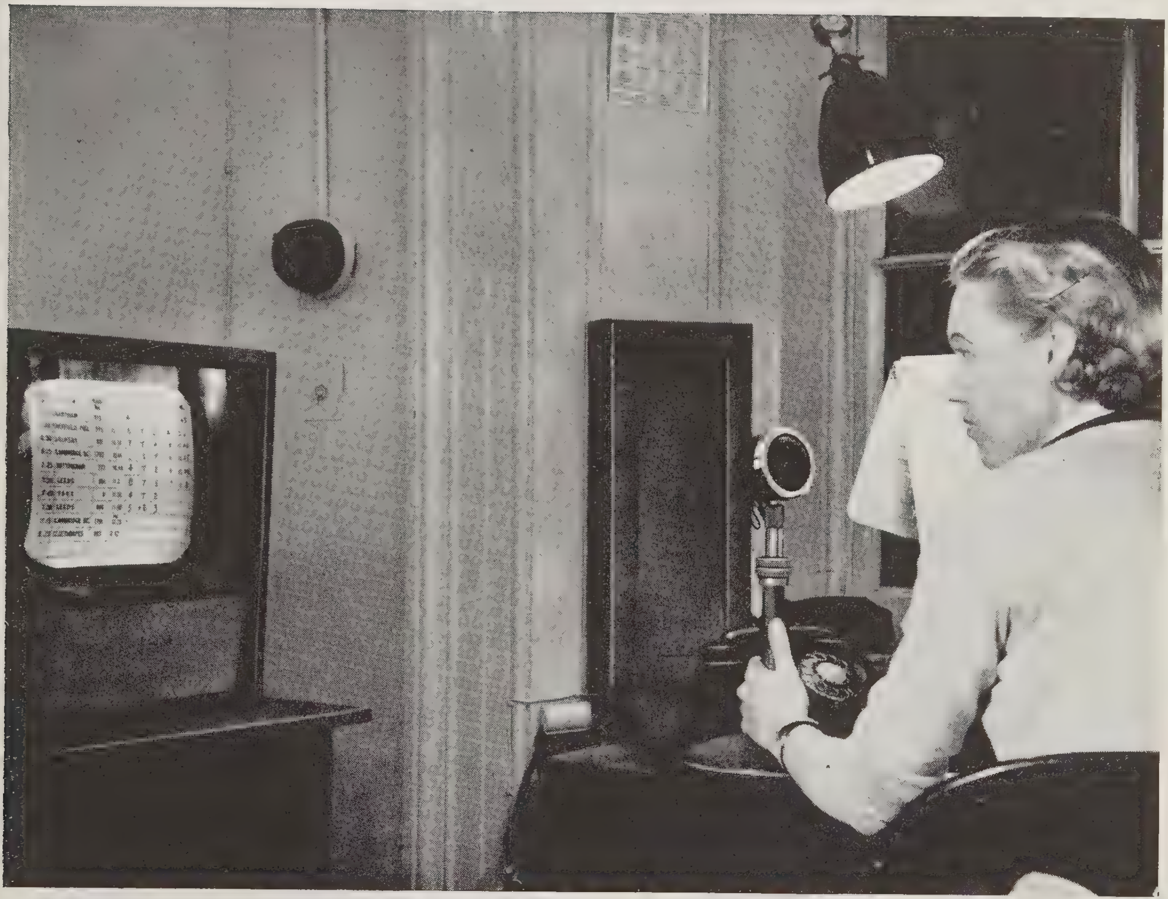
Information is transmitted continuously between the hours of 9.30 a.m. and 3.45 p.m. In addition, prices quoted on New York's Wall Street are transmitted from 3 p.m. to 5 p.m. Visual communication only is provided, no sound equipment being fitted. A one-way system is used, there being no need to communicate between the head office and the box at the Stock Exchange or between the head office and the other customers.

Before this system was installed, current prices had to be phoned through to the head office and to the customers every hour or every few minutes, depending upon the circumstances. Now up-to-date information is available immediately to anyone connected to the system merely by turning a selector switch.

A similar application, also designed to eliminate a considerable amount of telephoning between departments, has been adopted by British Railways. Information regarding the progress of express trains on their journey towards King's Cross Station is required

Information is transmitted from the Stock Exchange "box" on ten channels. A dial switch at the receiver enables the viewer to select any one of the ten transmissions. Each channel conveys the prices of 48 *shares*

Deccafax system in use at King's Cross Station. Information is transmitted from the station signal box to other departments. One of the receivers, shown here, provides an information display in the train announcer's office



simultaneously by many departments at the station. Under the old scheme of things, the times of the trains as they passed through the distant stations of Peterborough, Hitchin and Hatfield were telephoned to the signal box at King's Cross. From here the information was relayed to other departments by an internal telephone system. Now the same information is passed on by a Deccafax system. A transmitter is located in the signal box and the relevant details of each train are noted on a prepared transparency. Permanent data displayed on the transparency are the train number, departure time, arrival time and starting point. Variable data written on the transparency are: the number of minutes the train is ahead or behind schedule and the number of the arrival platform.

This communication system lends itself to many other types of work. One that may be of value in highly mechanized industries, especially those where installations cover a larger area, is that round-table conferences involving documents can be conducted by the managers responsible for running the plant without the actual need to foregather.

How Raleigh Industries administer

An unusual and probably unique data processing sequence, with which Raleigh Industries update 25,000 credit-sale accounts each day and also produce any reminder letters that are necessary. A computer performs the calculations and administers customers' accounts automatically—unless and until a particular customer is so much in arrears that an individual and personal investigation is necessary.

Besides performing all the routine work, the computer produces statistics for management, checks the accuracy of information recorded on receipts issued by dealers and also checks the cash returns made

INDIVIDUAL repayments made under a credit-sale agreement are generally worth only a few shillings. In addition, the administrative work involved is complex. Although repayments are supposed to be regular amounts paid at fixed intervals, in practice this seldom occurs. Frequently a customer pays more than one instalment at a time or maybe only part of an instalment. With this degree of variation and the large number of weekly payments involved, an extremely efficient accounting procedure must be created to handle this work if the costs of administration are not to get out of proportion. Raleigh Industries, Limited, the largest manufacturers of bicycles in the world, assist retail dealers who do not wish to finance their own credit sales and, more especially, those who do not want the worry and trouble of administering their own schemes. A special company, Raleigh Industries (Gradual Payments), Limited, was established over 50 years ago to control and administer this work from a central office at Nottingham, the headquarters of the company. A Powers-Samas Programme Controlled Computer (PCC)* has recently been installed to

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*The Powers-Samas PCC is built by International Computers and Tabulators, Limited. It costs approximately £20,000. Performance figures and a brief specification of the machine appeared in the January-March, 1959, issue of *Data Processing*, page 42.

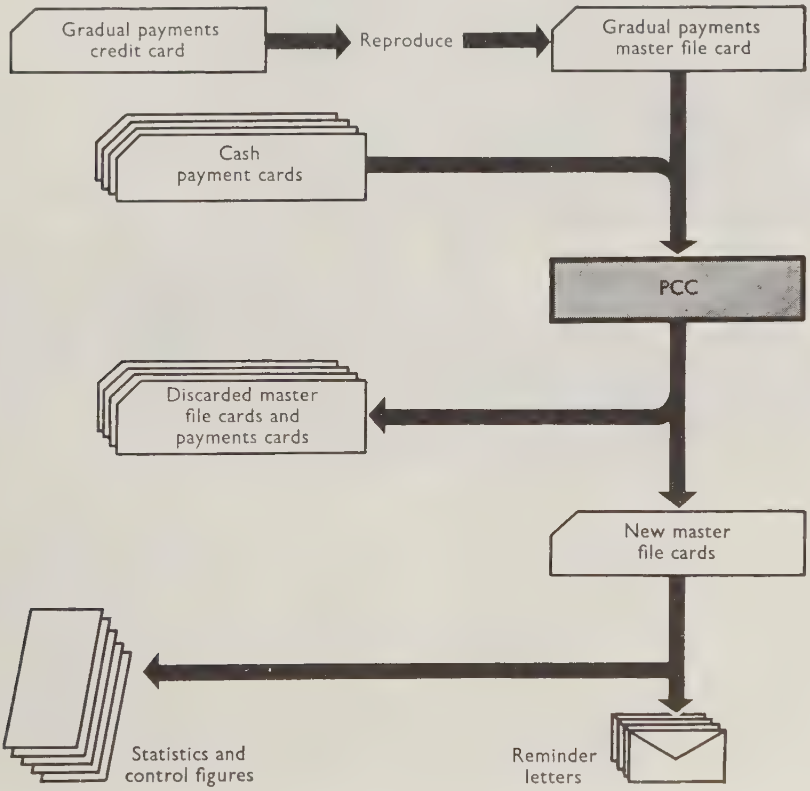
Part of the central machine accounting office in which all the work concerned with credit sales is performed. About 50,000 punched cards are handled by the Powers-Samas computer each day

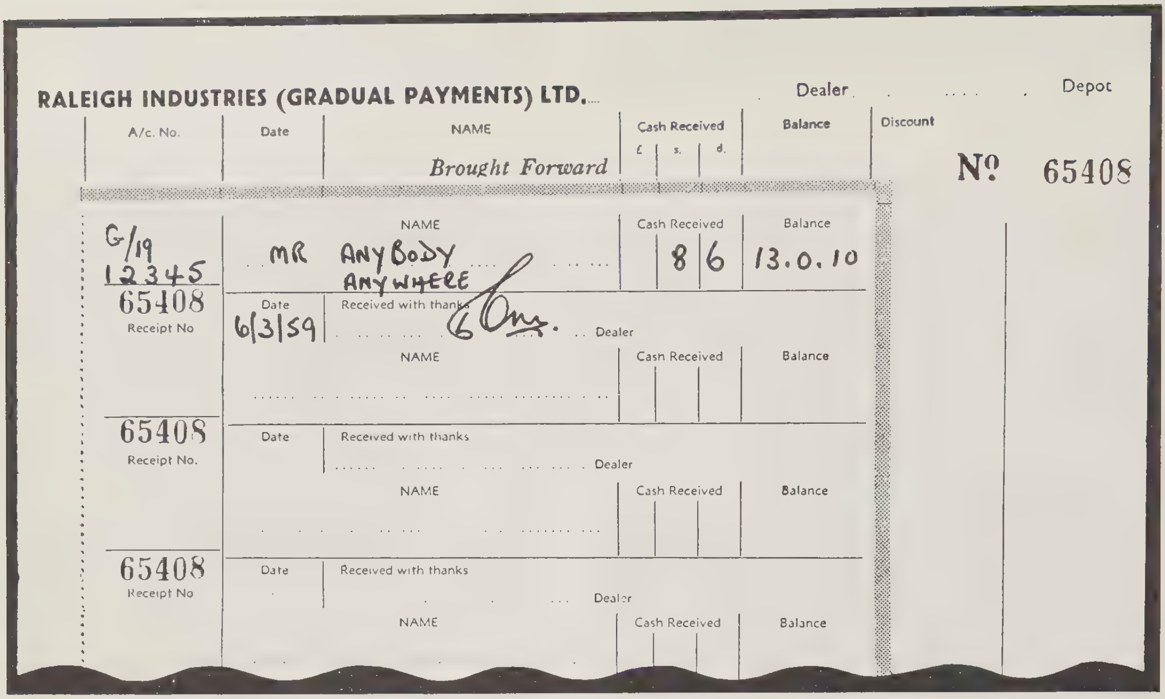
250,000 credit-sale accounts

enable data connected with credit sales to be handled more rapidly. The administrative procedure has also been improved. It has been extended so that reminder letters for customers who are behind in their payments are prepared automatically from the data produced by the computer. This latter sequence, an important innovation by Raleigh, removes the routine clerical work from the accounting office leaving the staff free to concentrate on work requiring personal attention and decisions.

Bicycles are sold, of course, by a large number of dealers located in all parts of the country. These dealers are not employees of Raleigh Industries, Limited, although, as far as credit-sale transactions are concerned, they act as collecting agents. For this they receive a commission on the value of the accounts handled. A transaction starts when a customer chooses a bicycle and wishes to buy it under a credit-sale agreement. First, a proposal form is completed in duplicate by the dealer; the original is sent to Raleigh Industries (Gradual Payments), Limited, and the copy is handed to the customer. If the information on the form is satisfactory, the proposal is accepted. At this stage the bicycle, which in the first place was bought by the dealer from Raleigh Industries, Limited, is bought back from the dealer by Raleigh Industries (Gradual Payments), Limited, at the retail price less the deposit paid by the customer. The account is then given a number by which it will be identified in all subsequent data processing sequences. In addition, a payment booklet is prepared and sent to the customer; this gives details of the value of the bicycle bought under the agreement, the deposit made, the outstanding debt, the amount of the weekly instalment and the number of weeks the agreement is to run. Repayments are normally spread over a

Data processing sequence. Customers' accounts are updated once a fortnight and reminder letters to those in arrears are prepared automatically


Gradual payments credit card
Reproduce
Gradual payments master file card
Cash payment cards
PCC
Discarded master file cards and payments cards
New master file cards
Statistics and control figures
Reminder letters



RALEIGH INDUSTRIES (GRADUAL PAYMENTS) LTD. Dealer Depot

A/c. No.	Date	NAME	Cash Received £ s. d.	Balance	Discount
		Brought Forward			

Nº 65408

	NAME	Cash Received	Balance
G/19 12345	MR ANYBODY ANYWHERE	8 6	13.0.10

65408 Receipt No
Date 6/3/59
Received with thanks ... Dealer

NAME	Cash Received	Balance

65408 Receipt No.
Date
Received with thanks ... Dealer

NAME	Cash Received	Balance

65408 Receipt No
Date
Received with thanks ... Dealer

NAME	Cash Received	Balance

Part of a set of three pages from a dealer's receipt book—the top page comprises 10 *perforated receipts. Details of a payment are entered on one of the slips which is torn out and stuck in the customer's payment book. The carbon copy on the second page is sent to the central accounting office; the remaining copy is the dealer's record*

period of 52 or 78 weeks. A carbon copy of the information contained in this booklet is filed in the library of current accounts.

Each accepted proposal is then passed to the machine-accounting section, where a credit note punched card is prepared. These cards have two functions: first, to provide a means of crediting the dealer with the retail price (less deposit) and any bonus earned; secondly, to provide a means of introducing new accounts into the gradual payments system. Next, a copy of relevant information on this card is automatically punched in a second card by a reproducing punch. The new card, called the opening debit card, contains the following information: dealer's number, customer's account number, customer's surname, opening balance, length of agreement, type of goods, weekly instalment and maximum discount obtainable. New opening debit cards are placed in the existing master files of punched cards which contain all the current accounts.

Each dealer operating the scheme is supplied with a receipt book (a set of pages from one of these books is shown in the illustration). The top sheet consists of 10 perforated receipts. When a customer makes his weekly payment, the dealer enters on one of the receipts the customer's account number and name, the date, cash received and the balance outstanding. He then tears off the receipt and sticks it in the customer's payment record book.

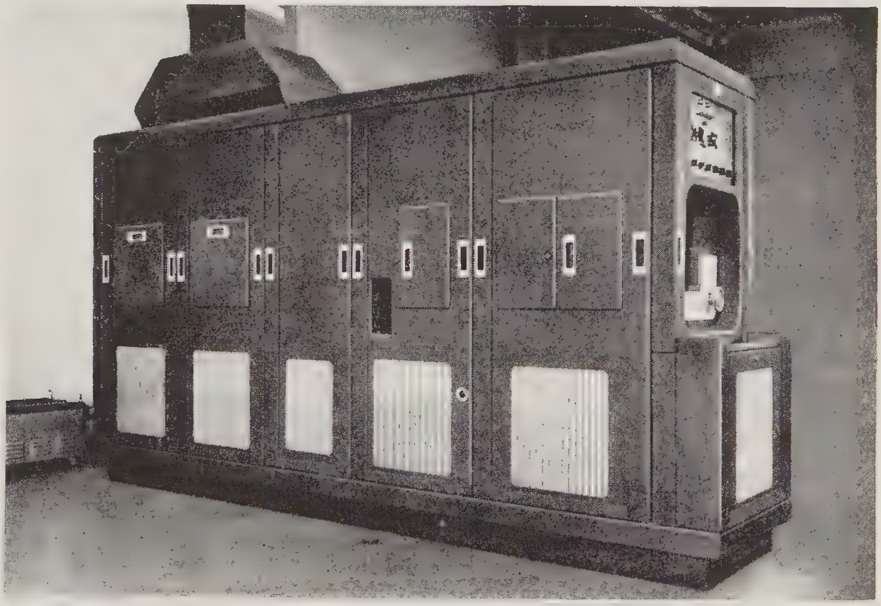
The weekly instalment stated on the proposal form is the minimum payment the customer has to make each week if his account is not to fall into arrears, but he can pay more if he wants to conclude the agreement earlier. In such cases he will receive a rebate.

Two carbon copies are made of all receipts. One carbon is retained by the dealer and the other, together with the cash collected, less commission, is sent to the central office at Nottingham. Cash-collection lists are forwarded once a week.

Cash payment card

On arrival the sheets are checked for continuity and legibility. In the card-preparation section, one card is punched for every cash payment made. This card is called the cash card. Information punched includes dealer's and customer's account number, date, receipt number, cash paid and balance recorded by the dealer. These cards are, of course, balanced with the totals recorded on the cash-collection lists. After this proof, the cards are filed in date order.

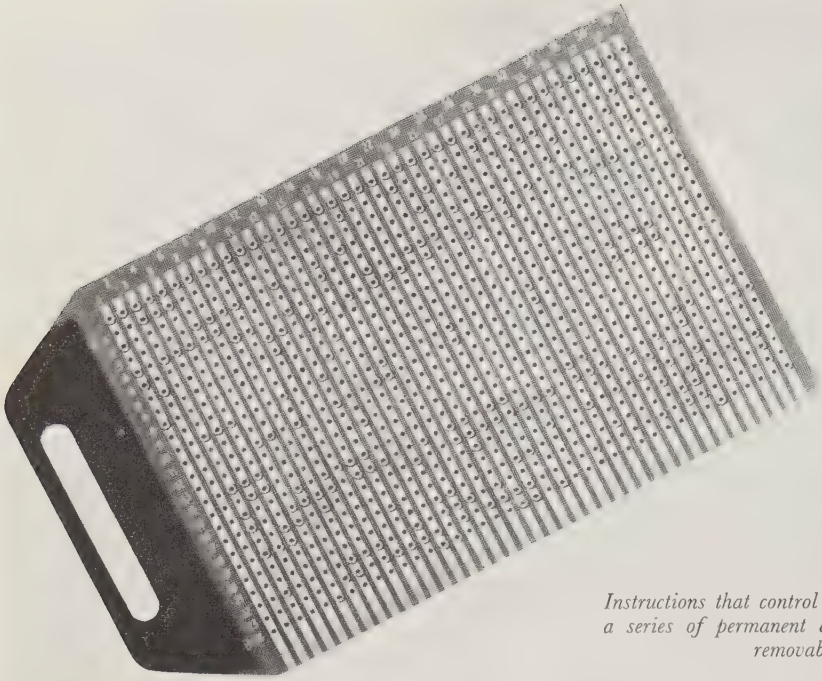
An interpolator merges cash payment cards with their appropriate master cards. Master cards without corresponding payment cards are rejected into a separate magazine of the machine



The Powers-Samas Programme Controlled Computer or PCC which performs all the calculations connected with credit-sale work. Input and output data are recorded on punched cards that are handled at the rate of 120 *cards a minute*

Each account is updated once a fortnight and, as something approaching 250,000 accounts are active and the load is spread over 10 working days, 25,000 accounts are processed each day.

All the relevant details of a current account are recorded on a master card. Before an account can be updated, it is necessary to bring together cash payment cards with their corresponding master cards. This is not a straightforward merging operation and two runs on an interpolator are necessary. In the first run, cash payment cards, sorted into account number order, are placed in one input hopper of the interpolator and master cards into the second input hopper. The interpolator will examine cards drawn from both hoppers in turn, and reject into a separate magazine all cash cards without a corresponding master card.

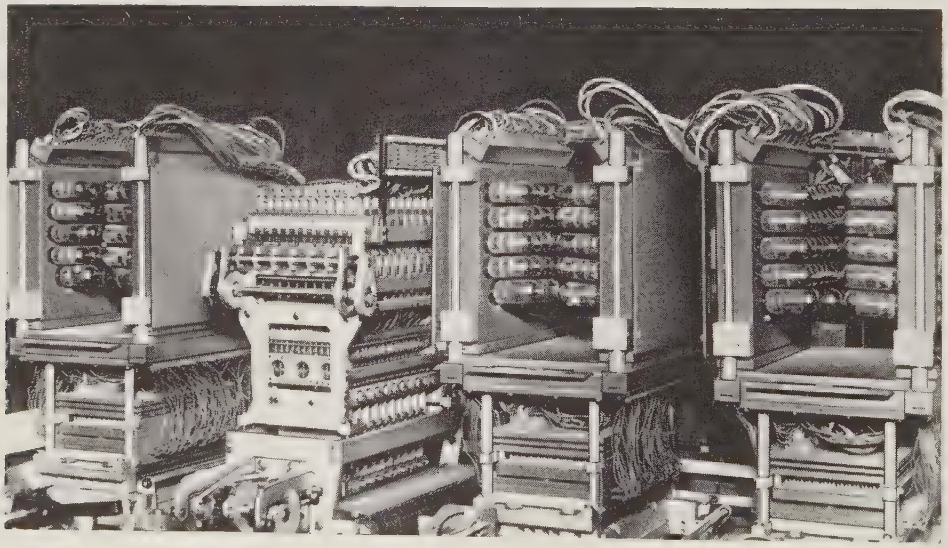


Instructions that control the operation of the PCC consist of a series of permanent electrical connections mounted on a removable programme board

Cash cards rejected during this run represent queries. For example, a customer may have gone into a shop without his payment booklet and given the wrong account number. Alternatively, the dealer may have made a mistake. Whatever the reason, this operation saves a lot of clerical work that would otherwise be needed to check physically each account number written on the cash-collection lists. Routines of this type have been devised so that manual work performed is kept to a minimum.

After this run, the cards are fed through the interpolator a second time when master cards and corresponding payment cards will be merged together in one pack and unaccompanied master cards will be rejected into a separate magazine. Master cards accompanied by cash payment cards indicate that the account has "moved" since the last updating run. The two packs of cards for moved and unmoved accounts produced by this operation are processed separately by the Powers-Samas PCC.

Information is read from or punched into cards at these four stations within the PCC computer

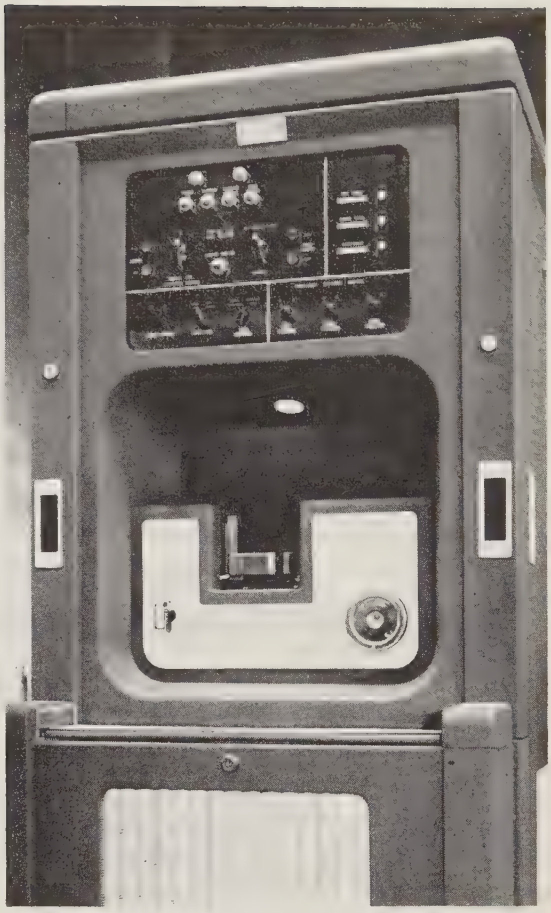


The PCC is a computer designed to be integrated with existing punched card machinery. All input and output data are recorded on punched cards. Cards pass through the machine at 120 per minute. The PCC is not a stored-programme computer, where the programme that will determine its operation is read from punched cards, or tape, and stored within the machine. Programmes for the PCC are created permanently by making a series of electrical connections on a programme board. When a programme is to be changed, the programme board is removed and replaced by another. A programme of 160 steps can be accommodated. The programme devised for the job of credit sales has 158 steps.

Four stations are provided within the computer. At the first station all the data required for the computation are read from the card. At the second station the same data are read again and compared with those read originally. This confirms the accuracy of the reading operation. At station three the result is punched into the same card from which the original factors were obtained. At station four the results punched at station three are read from the card and compared with a second answer that has been obtained by another computing circuit. If the two results are confirmed as being identical, the card is passed to the output hopper. Should an error be detected, the card is turned upside down. Incorrect cards can easily be found because, being reversed, their corners will project from the cut corners of the remainder of the pack. A counter on the control panel of the computer indicates the number of incorrect cards.

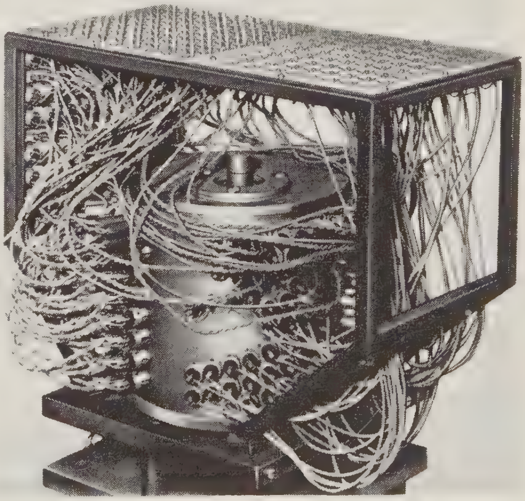
Let us consider the data processing sequence for moved accounts. Cards are fed into the PCC from the input hopper, one at a time. The first card in any group connected with one account will be the master file card followed by one or more cash payment cards. As the accounts are processed fortnightly, and payments are made weekly, generally two cash cards will follow each master file card.

When the master file card reaches the first card station, all the data punched in the card are read from it and recorded on the magnetic drum of the computer. Among the data read will be the account number and all the cash balances. As each cash card reaches the first reading station, the account number recorded upon it is read and compared with the number read from the master file card that preceded it.

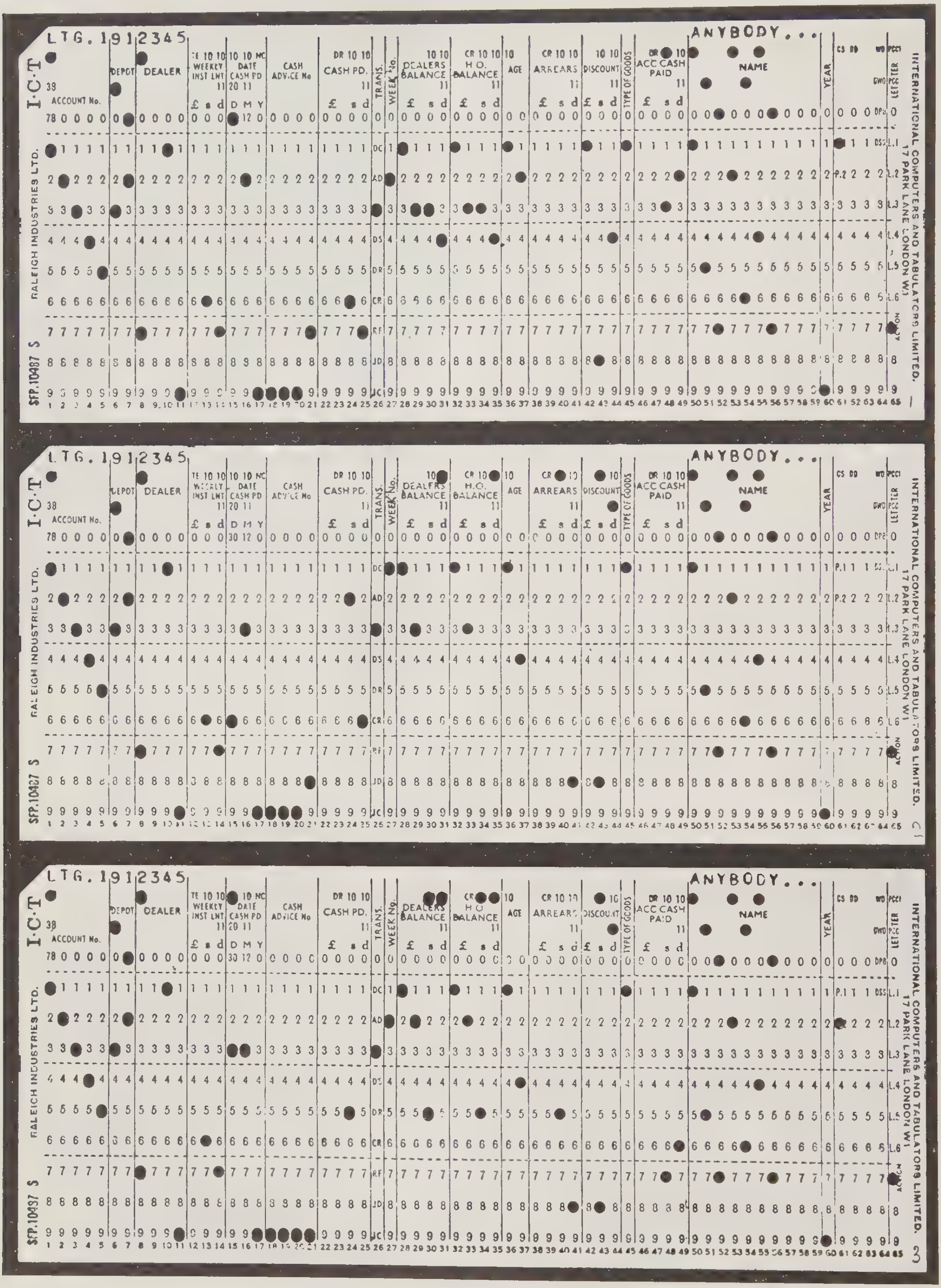


Control panel of the PCC. A counter is provided to indicate the number of incorrect cards passed through the machine. Below the panel is the hopper where cards are placed

All data read from a card are recorded and stored on a magnetic drum fitted to the computer



Sequence of cards as they are fed into the computer. The top card is the master card. Immediately below are two cash payment cards. The updated information is punched into the final cash payment card which then becomes the new master card



If these agree the cash paid is read from the card and the figures held in store. If the account numbers disagree, the cash card is inverted and passed through the computer, no further action being taken. When the last cash card belonging to one account has passed through, the total of the cash paid (an addition of all the separate amounts) is subtracted from the balance read from the master file card. The new balance is then punched into the final cash card of the group. This card will now be the new master file card since it contains the updated information. Cash cards and master file cards are of identical design.

This operation has been described as an entity in order to preserve the continuity of the description. While this is going on, however, other data read from the card are being processed to obtain additional information about the status of the account. One of the most important operations, of course, is to determine whether the account is in arrears or not.

In columns 38 to 41 on the master file card are punched any arrears that existed when the account was last updated, that is a fortnight previously. The weekly instalment is also recorded on the master file card. This latter figure is multiplied by two and added to the value, if any, recorded in the arrears columns. The total derived is then subtracted from the cash paid. If the answer is positive it means the customer is ahead on his payments; conversely, of course, if the answer is negative it indicates that he is in arrears. The amount of the arrears, if any, is then punched into the new master file card.

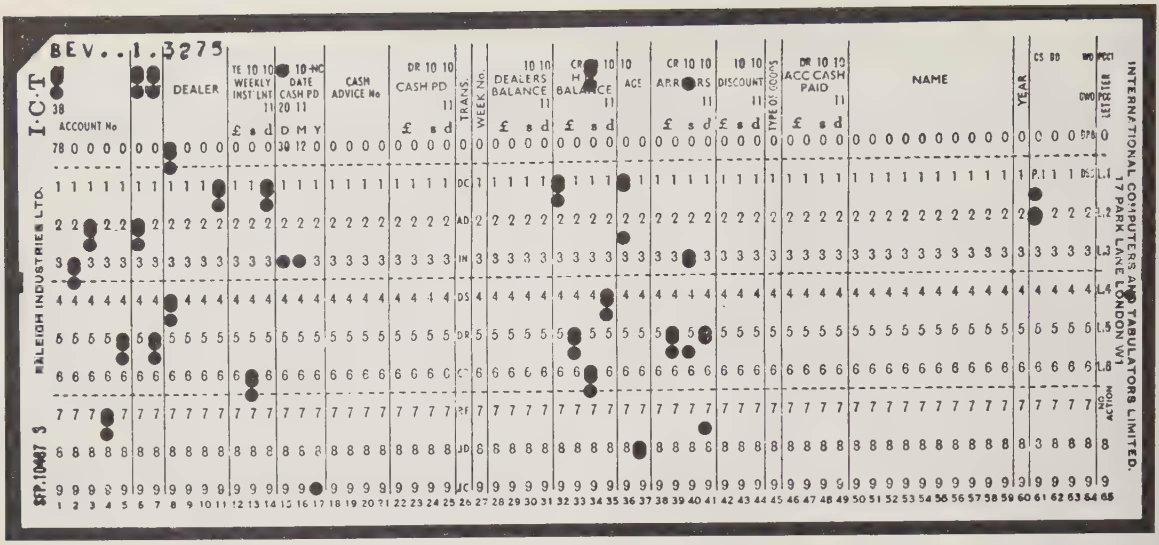
Some note must be kept of the age of the account, and this is recorded in columns 36 and 37 of the card. Each customer, it will be recalled, agrees to repay the amount he owes over a fixed period of either 52 or 78 weeks. A code number punched in the card indicates the number of weeks the agreement has run and every time the account is processed this number is increased by two. When this number is the same as the term specified in the agreement, the agreement will have run its full course. Should the customer repay all the money he owes before the agreed completion date, a discount is earned and the computer will calculate this and enter it on the card. Should he not have completed payment by the agreed date, no further additions will be made to the arrears recorded at that date because, of course, this will be the total amount that remains outstanding on the account.

Another calculation performed at this stage is to compare the new balance obtained by the computer with the outstanding balance as recorded by the dealer on the written receipt given to the customer and punched into the cash card. Any discrepancy will indicate that the dealer has made an arithmetical error.

If an account is in arrears, it is obviously important to know by how much. This is done by multiplying the weekly instalment by three and subtracting from the answer the value of the arrears obtained earlier in the calculation. If the answer is positive it indicates that the customer is less than three weeks in arrears. If, however, the answer is negative, it will show that the customer is over three weeks behind in his payment. Where this is so, the weekly instalment is multiplied by five and the calculation, just described, is repeated. This procedure is continued until the number of weeks the customer is in arrears is known. A special code hole is punched in the card to indicate the arrears situation. When the account is more than a specified number of weeks in arrears it is placed in a special file to be administered manually. If the company agrees to the customer suspending payments, or to accept less than the stipulated weekly instalment, a special hole is punched in the master card and this account will be dealt with in a similar way.

This concludes the work performed by the computer on those cards for accounts that have moved. Only the major points of the computer sequence have been detailed. All the calculations described as well as many more subsidiary computations that have not been mentioned, are completed in half a second. Thus the cards pass through the computer at the maximum rate they can be handled, that is 120 cards a minute.

Master file cards for unmoved accounts are also passed through the computer and the same data processing procedure is performed. As no cash payment cards accompany these master cards, the outstanding balance will remain the same, but, of course, any arrears will be increased by an amount equal to two weekly instalments and the age of the agreement will be increased by two. However, as these cards are proceeding through the machine by themselves, the revised figures are punched at an inter-stage position in the card. If the design of a card is examined, it can be seen that it contains 12 horizontal rows in which holes are punched. The space left between two rows is



In master cards that are not accompanied by cash payment cards, revised data are punched in an inter-stage position—these punchings are made in the space between the normal rows

called the inter-stage position and is sufficiently large for a further series of holes to be punched. When the master file cards for unmoved accounts are removed from the computer, the updated information is reproduced into new master file cards in the normal positions and these are the cards carried forward to the next data processing operation. The reason this method of working is adopted is to conserve computing time.

A blank card could follow each master file card so that when the cards were passed through the computer the new data could be punched directly into the blank card in the correct place. Processing time, however, would be doubled.

This concludes the computing sequence. Old master file cards, cash payment cards and new master file cards will be contained in the packs as they are removed from the computer. The first job is to separate the new master file cards from the remainder and this is done by a sorter. A special code hole has been punched in all new master cards by the PCC for this purpose. Old cards can be discarded as they are no longer required, together with cards belonging to accounts that have been settled.

Cards belonging to accounts that have moved and those that have not moved are then re-merged and arranged in account-number order. Various lists can be printed on a tabulator from the data contained on the cards. Total amounts of cash due from each dealer can be obtained. These totals are agreed with totals derived by other methods to ensure that the calculations have been performed correctly.

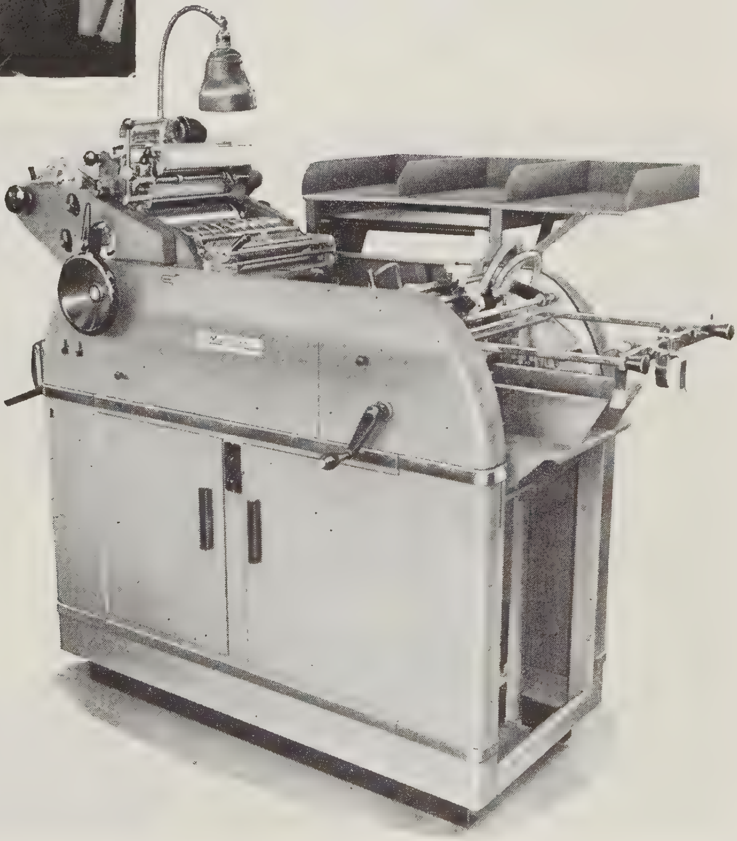
From an administrative point of view, the preparation of reminder letters to those customers who have fallen into arrears is one of the more important jobs performed and certainly a most unusual data processing procedure. It will be remembered that when the amount of the arrears is being calculated a special code hole is punched into the card to indicate the severity of the situation. There are several categories of severity, each indicated by a different hole. Cards for accounts in arrears are sorted into these categories and tabulated together with the associated name and address cards. Thus the sheets printed will contain a list of customers' names and addresses followed by the amounts of the arrears.

These printed lists are next passed through a Multilith document-printing machine which will overprint the wording of an appropriate reminder letter. Naturally the name and address data together with the arrears are positioned on the paper so that they coincide with the blank spaces left in the letter overprinted by the Multilith machine. The printed continuous stationery is cut into individual letters as the sheets emerge from the printing machine and the separate letters are automatically inserted into envelopes by another machine. In this way the majority of the routine correspondence connected with the credit payment work is dealt with automatically. Accounts on which the company has agreed to accept less than the stipulated weekly instalment or are more severely in arrears, are included in a special category and are dealt with personally as individual decisions will be needed to meet the particular conditions.

Besides providing all the routine data for the credit sales scheme, the computer produces statistics for management once a month. With the old manual method of working only rudimentary statistics were available. Now with the aid of accurate statistics, management is able to exercise more effective control.

In a normal working day, about 50,000 cards will pass through the PCC computer. The machine is occupied solely in performing this work although Raleigh Industries are contemplating preparing other programmes for the machine. If these are put into effect, the PCC will be operated for 16 hours a day, instead of the present eight hours.

Customers' names and addresses, together with amounts of arrears, are printed on a tabulator



Over-printing the text of a suitable reminder letter by means of a Multilith machine

Robot bank clerks

Four machines designed to mechanize the clearing of cheques and the updating of accounts. Manufactured in Belgium, the machines are being used by a New York bank

A system, simple in conception, which is unusual in that the documents—the cheques and the customer's paying-in slips—accompany the data as they are processed, from start to finish. Details of customers' accounts recorded on magnetic tape are updated automatically and information about overdrawn accounts or unusually large transactions are printed out for the attention of management. While the methods have been developed to speed up banking procedures, there are many other potential applications

ORIGINALLY, the Bell Telephone's data processing system was designed to meet the special requirements of United States banking practice. The feature that distinguishes the system from all others is the way in which the original documents accompany the information as it passes through the various processing stages.

The aim of the design is to speed up the task of clearing cheques and updating current accounts. Three of the four machines that comprise the system are now in use in a New York bank and the fourth is at present undergoing test at the maker's factory. A modified version of the system is also being produced for the banking department of the Belgian Postal Cheque Office. The machines are designed and built by the Bell Telephone Manufacturing Company, of Antwerp, Belgium.

Each document, or cheque, is placed in a transparent plastic jacket that has, attached to the top edge, a stiffened flat strip that extends beyond the sides of the jacket. Also attached to the upper edge is a strip of magnetic tape 1 inch wide and approximately 7¾ inches in length. All the relevant data to be processed are recorded on the magnetic tape and the document from which they were obtained is enclosed within the jacket. This combination of jacket and document constitutes the basic information element in the system. All the jackets are of a standard size and can be used any number of times Documents up to a maximum of 9·1 inches by 4·7 inches can be accommodated.

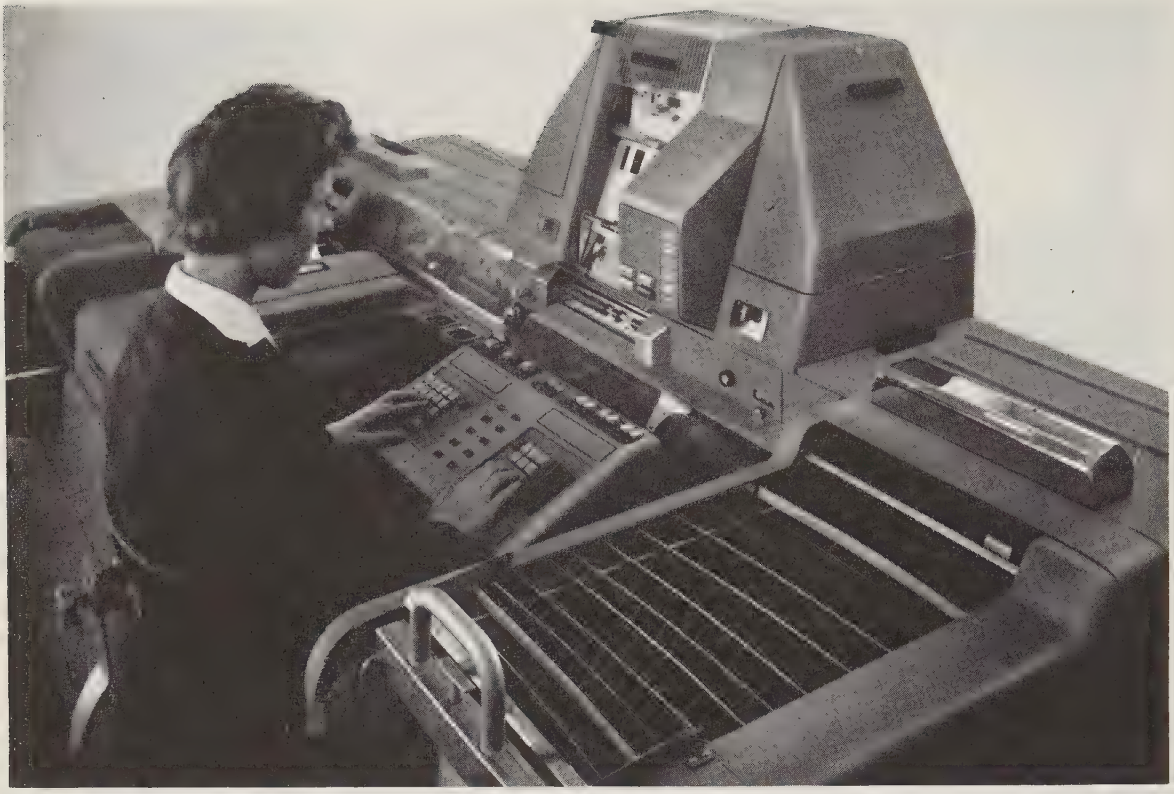
As the jackets are fed into the various machines they are transported mechanically to the operating positions by endless chains on which the protruding extremities of the stiffened bar of the jacket rest. Information to be processed is read from the magnetic tape.

The four machines comprising the complete system are the jacketing machine, the classifying machine, the unjacketing machine and a unit referred to as the account posting group.

As its name implies, the jacketing machine places the documents in the jackets; it also performs the other equally important task of recording the data on the magnetic tape. The machine has a U-shaped console at which the operator sits. Immediately in front of the operator is a keyboard and above this a reading position where each document is displayed in turn. Above this again is a hopper in which all the documents to be jacketed are placed by the operator.

Operation of the equipment will be described as though cheques were being processed although, of course, other types of documents can be handled. A bundle of cheques, plus the customer's deposit slips, is placed in the hopper. They are then fed in sequence, one at a time, to

Each document or cheque is enclosed within a transparent plastic jacket. Data, obtained from the document, are recorded on a strip of magnetic tape which is attached to the upper edge of the jacket. This combination of jacket and document forms the basic element of information. Data are read from the magnetic tape when the jackets are fed into the various machines. Jackets can accommodate documents up to 9·1 inches by 4·7 inches in size



Two jobs are performed by the jacketing machine. Data entered on the keyboard are recorded on the magnetic tape and, secondly, the document is placed in the jacket

the reading position. The operator enters on the keyboard all the relevant data such as the code number of the bank, branch, account number, type of entry and amount. These data are converted into decimal binary code* (a 2421 code is used) and sent to an information store where they are retained. When the operator depresses the "enter" button the data in the information store are recorded on the magnetic tape of an empty jacket that has been positioned at the writing station in the machine.

Before the jacket is sent to the position where the document can be placed in it, the accuracy of the information recorded on the tape is checked automatically. This is done by the machine reading back the data just recorded on the tape and comparing them with the data still retained in the information store. If these are confirmed as being identical, the jacket is transported to the loading position where it is opened, the cheque is dropped in and the jacket is closed and then conveyed to the output storage compartment. After the electronic check has been performed satisfactorily the data in the information store are discarded and all is ready for the next transcription.

The magnetic tape fixed to the jacket has two tracks. One is a reference or "clock" track used to align the jacket with the various electro-magnetic reading and writing heads. The other is the information track on which are recorded the data the operator entered on the keyboard. Provision has been made initially to record two blocks of data on the information track each containing 26 digits. The second block is similar to the first, but recorded in a complementary form in order that various electronic checks can be carried out to confirm the accuracy of subsequent operations. These two blocks occupy approximately 1·6 inches of tape; therefore, as the tape is about $7\frac{3}{4}$ inches long, considerably more data could be recorded if needed.

For a description of decimal binary codes see "The Universal Language of Computing," pages 18-20, Data Processing, *January-March,* 1959.

To confirm that the operator has entered the correct data on the keyboard, the information transcribed is printed out on a tally roll at the same time as the entry is made. At the conclusion of a sequence of entries a total will be printed automatically on the tally roll. A comparison is made with the total given on the document from which the data are being transcribed. If there is a discrepancy, then each entry can be compared separately to determine the one at fault.

Working speeds, of course, depend on the skill of the operator and the number of key depressions that have to be made for each document. On the basis of an average of 15 key depressions for each item, some 700 to 800 documents can be jacketed in an hour.

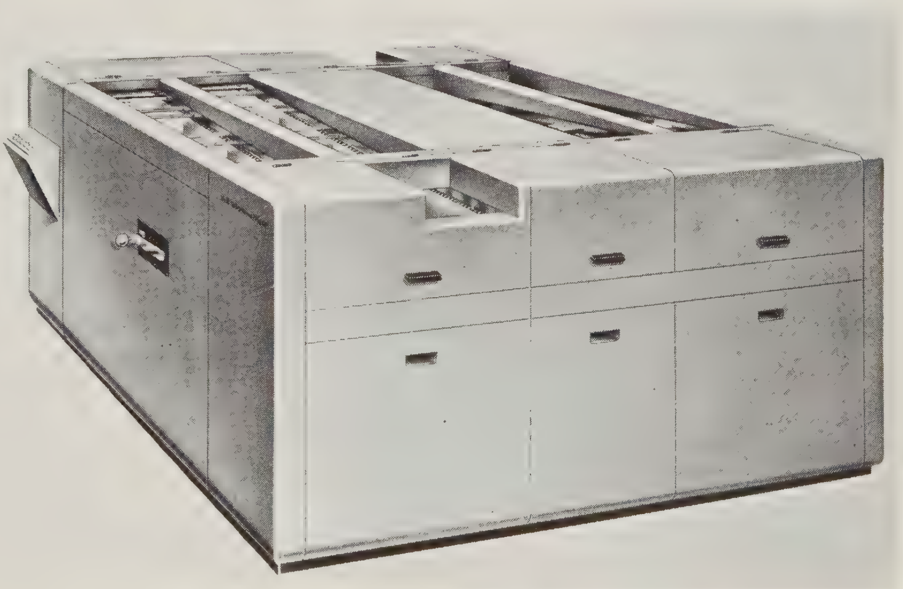
Automatic checks

Various automatic checks are carried out to ensure correct operation. In the banking application, all account numbers have seven digits to which an eighth proof digit is added. These eight digits conform with an arithmetical law that the electronic circuits recognize, and should the operator have transposed two digits or pressed the wrong key the error will be detected and an alarm given.

Three adding registers are also fitted in the machine. On the first are entered the amounts of all transactions, including the cash items relating to one account, and a total is provided at the conclusion of the entry. Cash totals for the day are summed on the second register, and the third register checks that the debit and credit totals agree. This is known as the zero proof calculation. It will be recalled that all cheques are accompanied by a deposit slip on which the customer totals the value of the cheques listed. As the deposit is a credit, or positive entry, and the cheques are debits, or negative entries, the cash value recorded in the third adding register should be zero because the total value on the deposit slip should be exactly equal but of opposite sign to the sum of the values on the individual cheques.

The second unit in the system is the classifying machine. The function of this is to sort the documents into numerical order and all the operator has to do is to load batches of jackets into each of the two storage tracks located at the input station. These jackets will be arranged in a number of short numerical sequences. A sequence consists of a group of jackets arranged in ascending order of magnitude. A batch of jackets in completely random order will contain, by chance, many two-jacket sequences and an occasional three-jacket sequence. Sorting is performed by successively merging a sequence of jackets taken from each storage track.

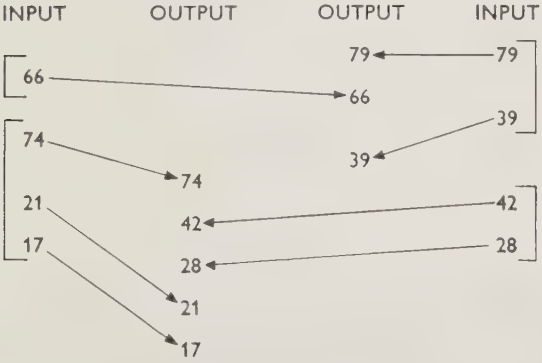
First, the jackets are transported to a reading station situated at the end of the two tracks. Here the serial number on the first jacket in each track is read and sent to an information store. The jacket bearing the lowest value is


Jackets are sorted automatically into numerical order by the classifying machine. Up to 1,500 jackets can be handled at a time

released and transported mechanically to one of two output tracks. The next jacket is moved into the reading position in the storage track, the serial number is read from it and sent to the information store where it is compared with the serial number of the jacket remaining from the previous operation. The jacket with the lowest serial number is then delivered to the same output track. This procedure is repeated until all the jackets in the first two sequences have been dealt with.

The next two sequences of jackets arriving at the reading station are processed in the same way. However, the jackets produced by the merging of these two sequences are sent to the second output track. Eventually, all the jackets in the input storage tracks will have been dealt with, every pair of sequences having been directed alternately to one or other of the two output tracks.

As an example of the principle of sorting by merging sequences, consider the table below. Square brackets enclose existing sequences: jackets from two input tracks are being merged and sent to one or other of two output tracks.



First, numbers 17 and 28 at the foot of the table are compared and the lower number (17) is sent to one of the output tracks. Next, in order, 21 is compared with 28 left from the previous operation and 21 being the lower is sent to the same output track. This procedure is repeated until all the numbers of the first two sequences have been dealt with. The jackets in the second pair of sequences are directed to the other output track. Although the numbers in the two output tracks are still not merged into a continuous sequence in one track, the individual "runs" are longer. For example, the two short separate runs, 17, 21 and 74 and 28 and 42, have been merged into one run, 17, 21, 28, 42, 74. If the two batches are merged again, individual sequences will become still longer and eventually, after a series of repetitions, all the numbers will be sorted into correct numerical order.

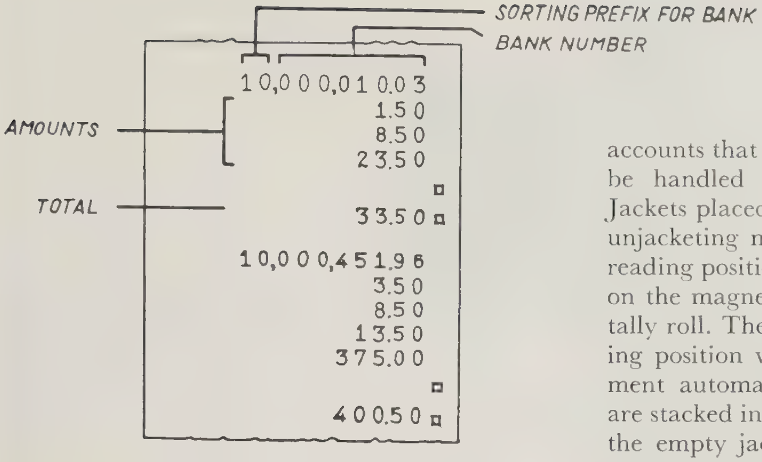
To enable this repetitive merging of jackets to be accomplished, the machine is provided with a second sorting stage that is a replica of the first stage already described. Here, the two input tracks are fed with jackets from the two output tracks of the first stage. Each stage is provided with a reject compartment into which are diverted those jackets that cannot be read correctly because of, say, damage to the magnetic tape.

Because the machine is built round four sides of a square, the two output tracks of the one sorting stage feed the two input tracks of the other stage. Jackets thus circulate continuously and automatically until all the jackets arrive in the same input track of the first stage of the machine. The machine then automatically switches itself off.

If a quantity of jackets in completely random order is put in the machine they will first be sorted into batches of approximately four. During the second merging sequence the jackets will be assembled in batches of eight. Consequently, nine merging operations may be needed to sort 1,000 jackets. Of course, a completely random arrangement of jackets at the start is unusual and short sequences will normally exist, with the result that fewer than nine sorts are required to arrange 1,000 items in correct numerical order. Since in one second, six jackets can be sorted, in one hour the machine can usually sort four sets of 1,000 items or merge 35 sets of 500 items already arranged in order. A typical load is 1,200 jackets, although up to 1,500 jackets may be loaded into the machine at one time.

One of the operational features of this system is that sorting time is independent of the number of digits in the number. In the banking application the cheques are sorted on the account number and the amount. This constitutes a 20-digit number.

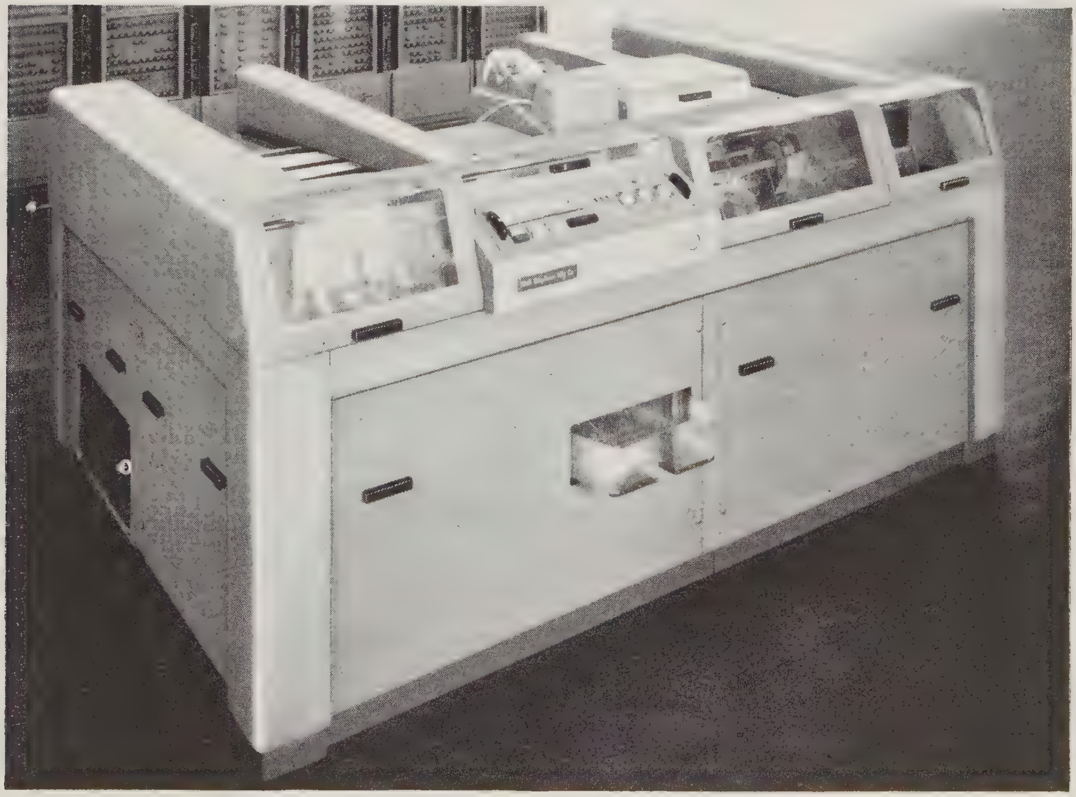
When the jackets are in correct numerical sequence they may be sent to either of the two remaining machines. Cheques to be returned to other banks will be passed on to the unjacketing machine while documents referring to local



Listing tape printed by the unjacketing machine

accounts that have to be brought up to date will be handled by the account posting group. Jackets placed in the input compartment of the unjacketing machine are transported first to a reading position. Here the information recorded on the magnetic tape is read and printed on a tally roll. The jacket then passes to the unloading position where it is opened and the document automatically removed. The documents are stacked in sequence in an output hopper and the empty jackets are conveyed to an output tray ready for use again.

An adding register is fitted to the unjacketing machine. For cheque clearing work the values of all cheques belonging to one bank and the total value are printed on the tally roll; at the conclusion of an unjacketing sequence the cheques are bundled together and, accompanied by the printed list, are returned to the appropriate bank.



Documents are automatically removed from the jackets by this machine. At the same time a list is printed of all documents unjacketed and totals are compiled

The operation of the unjacketing machine can be varied. It can be arranged for the machine to stop every time the bank number changes so that the operator can remove the cheques belonging to one bank before the next batch of cheques is unjacketed, or a counter can be set on the control panel to stop the machine when a particular number of items has been unjacketed, or the machine can be left to run until all the jackets placed in it have been handled. Approximately 3,000 items can be listed and unjacketed per hour.

The three machines described have been in commercial use in the United States for over a year. Further machines are being built and will be installed shortly. The fourth machine in the system, an account posting group, has been completed and is undergoing its final tests. This is a much more complex machine than any of the others—and is, in effect, a self-contained data processing system. It performs the unjacketing function and, in addition, updates the financial records of all customer accounts. For this work a digital computer is included together with large-capacity information storage facilities. The account posting group is completely automatic to the extent that it will post accounts in numerical sequence, yet reject those items for which there is an insufficient balance, or for which a "Stop" or a "Hold" instruction has been issued.

Magnetic tape files

All the accounting data are recorded on magnetic tape files. These files are unusual in that they are completely self-contained, each tape being an endless loop. Several tape units are included in one account posting group.

Information about customer's accounts is recorded on two of these tapes. On one, the financial tape, is recorded all the data that are liable to alter during a posting operation and on the other, the information tape, are recorded the permanent data relating to the account. Other tapes fitted to the account posting group are used to store the computer programmes and provide temporary storage for data being processed.

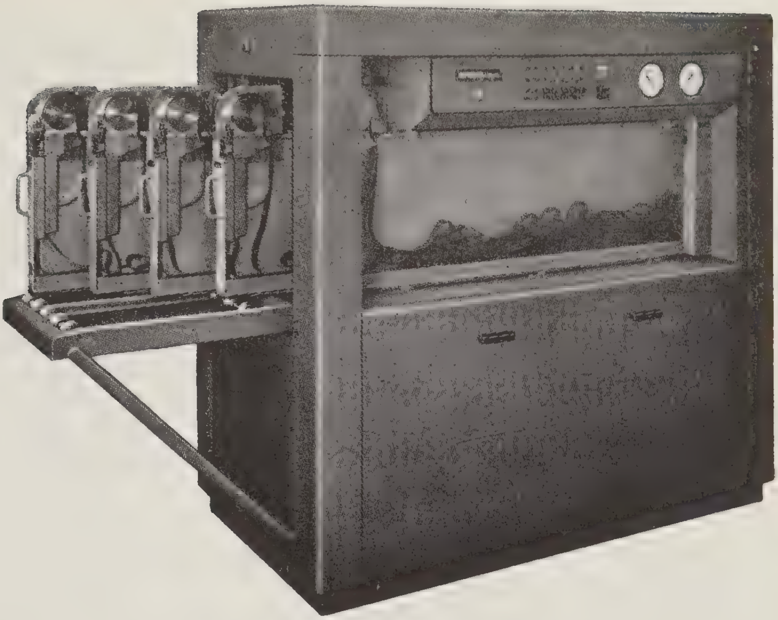
The magnetic tape is one inch in width and has 12 tracks. Two tracks contain addresses that enable the position of particular items of information to be identified. Two "clock" tracks are provided for synchronizing the feeding of the tape with the machine system. On the remaining eight tracks is recorded the accountancy information. Tape reading and recording speed is 100 inches a second and the recording density is 200 binary digits, or bits, to the inch.

Data are recorded on the magnetic tape serially along each track. During the posting, all the accounts located along one track round the complete tape loop are processed first. Then attention is switched to those accounts recorded on the second track. In this way the account data on each of the eight tracks are brought up to date in turn. Approximately 800 accounts can be recorded on one track; consequently, 6,400 accounts can be stored on each magnetic tape unit. Up to five units are fitted to one posting machine group, to give a total capacity of 32,000 accounts. The machine would be fully occupied on transactions connected with these 32,000 accounts and it is not intended that the magnetic tape units should be removed and changed to enable more than this number to be processed. If more accounts are active, a second posting group would be installed and the work divided between them.

Updating an account

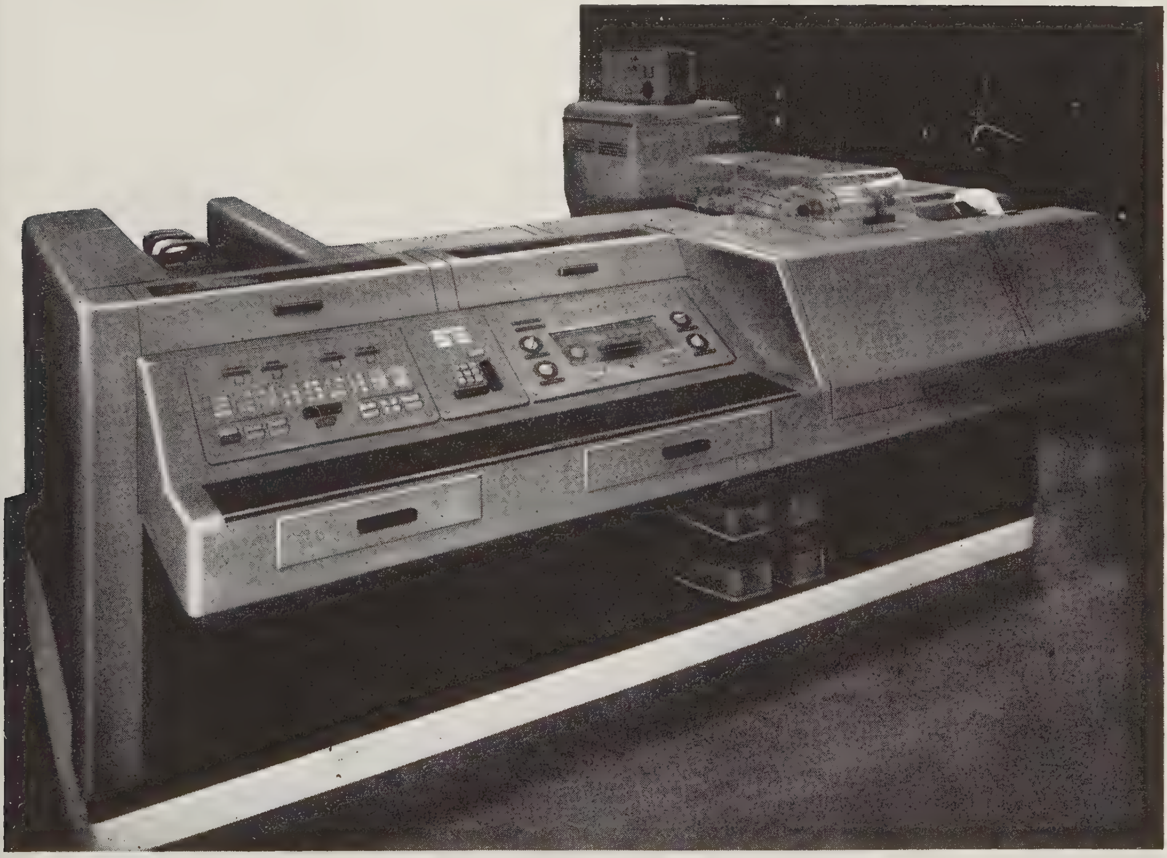
A typical bank posting operation proceeds as follows. First, all the data on one track of a particular financial control tape are copied on to another storage tape. This is done so that should something go wrong during the data processing sequence and the data on the financial tape be changed or overwritten in error, the original data are not lost; they are still available on the second, or copy, tape. The data regarding the transaction are read from the jacket and the track of the copy tape is searched until the appropriate account is found, whereupon the data are read from it. These two data are then combined and the revised data for that account are now written back on the original financial tape in the original position. The act of recording the new data automatically erases the old data—hence the need to have a copy of the original data on a second tape should anything go awry.

One complete track round a magnetic tape loop constitutes a control group—that is, after all the accounts in this group have been posted, a check is carried out. As the machine is posting the individual transactions, a register is summing the amounts of the original balances plus the new increments to those balances. At the conclusion of a posting sequence the financial tape is run through completely and the sum of all the balances obtained. This sum should then



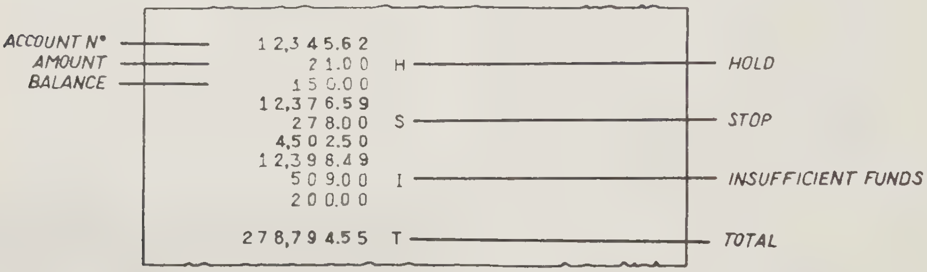
Four magnetic tape storage units shown partially withdrawn from the recording machine. The magnetic tape in each unit is in the form of a continuous loop

Central unit of the account posting group which handles the jackets, reads information from them and passes the data on to the other units within the group



equal the sum obtained when the individual posting operations were being performed. If this is so, the calculations and recordings have been completed correctly and it is safe to erase the data on the copy tape and proceed to post the next group of accounts. After the data recorded on the jacket have been dealt with, the jacket is passed to an unjacketing station where the enclosed document is automatically removed and stacked in an output tray. The jackets are then ready to be used again.

During posting, all the data are printed out by a line printer. Two copies of this document are produced, one for the customer and the other for the bank.



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 12,345.62
     21.00  H
    150.00
 12,376.59
    278.00  S
  4,502.50
 12,398.49
    509.00  I
    200.00

278,794.55  T
```

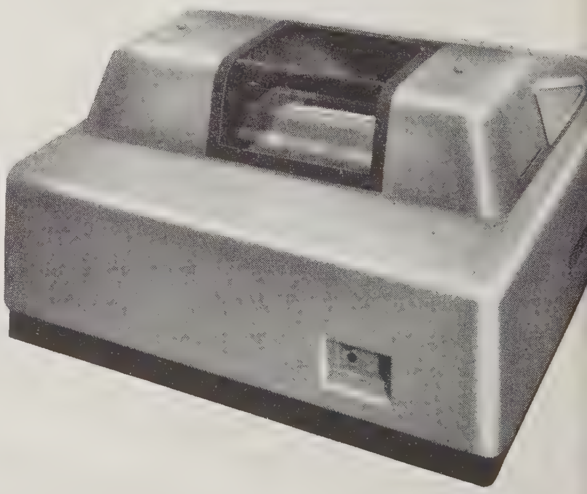
Listing tape produced by the account posting group

A symbol is recorded on the financial tape to show the type of account, account number, balance (11 digits plus sign), amount of debits, number of debits and number of credits. These last three items are assessed from the time the last balance statement was sent to the customer. Also recorded is a sequence number to indicate the order in which the various transactions were posted. This is to make it easier to trace a particular cheque should there be a query.

More permanent data concerning the account are recorded on the information tape. On this are listed the balance and the date of the last statement, bank charges to be levied and full details of the customer and the type of account.

One item of equipment included in the account posting group is a magnetic drum. This provides data storage capacity for the computational circuits associated with the group and also retains the special overriding instructions that are necessary in banking. One such instruction is "Stop." Any cheque issued against a "Stop" account will be rejected automatically by the machine and will not be posted.

A similar type of instruction is "Hold." In this case the machine will also automatically reject the cheque. An authorized bank official is then required to examine the cheque and decide whether it is to be accepted or not. Overdrawn accounts are handled in the same way; all cheques are automatically rejected for examination by an authorized bank official, who decides whether or not they shall be accepted. Unusual daily activities on any account such as exceptionally large deposits or withdrawals are also



A magnetic drum provides data storage facilities for the computing circuits of the account posting group printed out automatically and in this way brought to the immediate attention of the management. As the machine is always performing the same type of work, the programmes to control its operation are permanently recorded and stored on one of the magnetic tape units. The appropriate programme to perform a certain task is then selected by the operator pressing buttons on the machine control keyboard. New programmes can, of course, be devised and recorded as required.

Another piece of equipment associated with the account posting group is a random access desk. It is possible to interrogate the machine with this unit and obtain information, for example, on the state of a particular account. If the tape on which this account is stored is not being processed at the time, the required data will be read from it and printed out by an electric typewriter at the random access desk. This information can be obtained within 20 seconds. The random access desk is occupied principally in producing statements for customers at their request. Normally customer statements are prepared only at set times when a special programme is run that will produce automatically a separate printed statement for each account.

Important work performed by the account posting group is the production of these periodical statements and the maintenance of the current balances of all local accounts. On average, the account posting group can handle 3,600 items an hour.

Other types of work can also be performed. Of great value to bankers are statistical analyses obtained by collating selected data from particular types of accounts or those associated with particular industries or activities. Another clerical task performed is the accumulation of the daily balance of each account. The aggregate figures obtained are available at the time the statement is prepared and are used to decide whether a bank service charge should be levied against the account or not.

In addition, two further jobs are done by the accounting group. Accepted cheques are endorsed automatically and a photographic record of all documents handled by the machine is made on microfilm.

As has been stated, this approach to clerical data processing is unique in that the data and the documents proceed through the system together. These machines simulate manual clerical work more closely than any other automatic system yet devised.

The machine can be interrogated at any time and details of an account printed at the random access desk

Transferring work to a computer

By R. M. Paine.

A brief outline, for the benefit of management, of the planning stages that constitute the desirable preliminaries

In commercial applications, a computer's capabilities can only be utilized to the full if the work to be transferred to the computer is thoroughly investigated relative to its performance by machine and then definitely planned for machine operation. Planning the work for a computer is frequently called programming, though generally there are several stages to be completed before the actual list of coded instructions for the computer is compiled. These initial planning stages usually involve the preparation of various charts showing the source of the data, the sequence in which the data are to be handled and the operations to be performed on the data.

Much time and effort can be wasted by inefficient systems study and the failure to produce good charts—charts that will aid in showing management what it is intended to do, that will help in the formulation of the coding for the computer and that will be of real value for future reference. Logically consistent charts help the detection of errors in the computer programme, indicate shortcuts that might otherwise have been obscured because of the complexity of the problem and are invaluable when modifications to established computer procedures are being considered.

Preparation and planning of a data processing sequence can be divided into four main phases: a broad description of the main flow of work; a written statement showing the volume of work involved; a detailed graphical presentation of the data processing sequence; and the writing of the actual computer programme. The documents produced as a result of these four phases are the general process chart, the data statement, the flow chart and the computer programme.†

The general process chart indicates the general plan of attack, the source of data, the files and the equipment involved and the amount of sorting or collating required. The chart also gives a brief description of the data processing runs and of the punched cards, punched tape, magnetic tape or other documents produced. Other items include particulars of the auxiliary equipment required for a given job and the extent to which data are processed away from the computer.

The data statement is a written document, generally in tabular form, that amplifies the information given on the general process chart. Some people refer to this as the "digit count" because it gives the number of characters or digits that have to be handled. The data statement should include the following:—

Data Input—from where and in what sequence the data are obtained; how frequently they are needed; and the maximum number of digits that are required to describe each item. The documents on which these data are presented should be specified—punched cards, punched tape or magnetic tape.

Data Output—specifies what data are needed; in what form and how frequently the results are to be presented; whether they will be

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Mr. R. M. Paine is with Shell-Mex and B.P. Limited.

†An example of a general process chart is shown on page 180 and a flow chart on page 140.

used for another computer run; to whom the results should be sent; and how many copies are required.

Volume of Data—average and maximum volumes of data handled; occasions when peak loads will occur; the number of and frequency with which amendments will have to be made to permanent data held on file.

Checks—details of checks to be carried out to confirm the accuracy of the work performed; information on the type of error anticipated from the data preparation stage.

The data statement is, in effect, a statement of the data-handling requirements needed for a particular computer run.

A flow chart, prepared during the third of the four planning phases, is a detailed graphical presentation of the data processing sequence and is provided to aid the programmer in compiling the list of coded instructions for the computer. The chart is usually drawn up by the systems analyst and the programmer working in co-operation. It is, of course, necessary for the persons responsible for the preparation of the flow chart to know the capabilities of the computer and of its auxiliary equipment and thus be able to arrange for the tasks to be tackled in a logical sequence and the most efficient manner.

In scientific work it may not be necessary to draw up a detailed flow chart since the procedure generally follows definite rules that can easily be remembered. In commercial work, however, there are many exceptions to the general rule, many accountancy checks to be incorporated and many different documents to be produced, and increasingly there is a desire to integrate several related procedures. It is therefore impossible for any one person to keep clearly in mind all that has to be done. In these circumstances it is inevitable that points would be overlooked unless a detailed flow chart were drawn up. In addition, as most commercial programming and system studies result from a team effort, flow charts provide an essential medium of communication inside the computer department and also between the computer department and other departments whose work is to be performed on the computer.

When the instructions for the computer are being coded it may be necessary to alter the flow chart on the score that the scheme proposed does not permit the computer to handle the data in the most efficient way. For instance, a flow chart might have to be altered because the best way of sorting data was not known when the coding was started, or because the information store of the computer may be overloaded during a particular operation.

The purpose of a business flow chart is to clarify the requirements of the computer run. It should be easily understood by management and not cluttered up with over-elaborate symbols and mathematical expressions. The fundamental requirement is that the chart should show in pictorial form the logical flow of data through the processing sequence.

Although there are many different ways of preparing the charts, a most important point to establish is that within one company the method of presentation should be standardized.

The fourth and final planning phase is the task of converting the flow chart into detailed instructions for controlling the operation of the computer. The writing of this programme is very specialized work in spite of its being merely a restatement of the information on the flow chart. After this a considerable amount of work still has to be done in testing the programme as well as moving jobs on to the computer. Each programme produced is, of course, only suitable for the particular design of computer for which it is prepared, though in the future the development of automatic programming* may permit one programme to be used on several machines.

It has already been mentioned that as the computer programmer compiles the list of instructions it may be necessary to alter the flow chart to conform to the capabilities of the machine. All such alterations should be noted on the chart so that at any time another programmer can take over and understand what has been accomplished so far. Also, once the programme is working successfully, if any modification is required because of a change in the circumstances of the job, the flow chart can be consulted to see how this can best be achieved.

It is obvious from the foregoing that, of all the documents produced during the planning stages, the flow chart is one of the more important. It is not discarded once the computer programme has been written. Like an engineering plan, it is being referred to continually to provide basic information about the system. It is also constantly being modified as experience is gained in operating the data processing sequence and also as the system is extended.

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*See "Automatic Programming," *Data Processing*, page 26, January-March, 1959.

Numbers into graphs—

Machines that carry out these tasks automatically

Plotting 40 to 60 points per minute

Reading 1,000 points per hour or, for short periods with suitable charts, one point per second

Details of plotting machines which operate from punched cards, punched tape or magnetic tape and can lay out several curves at the same time

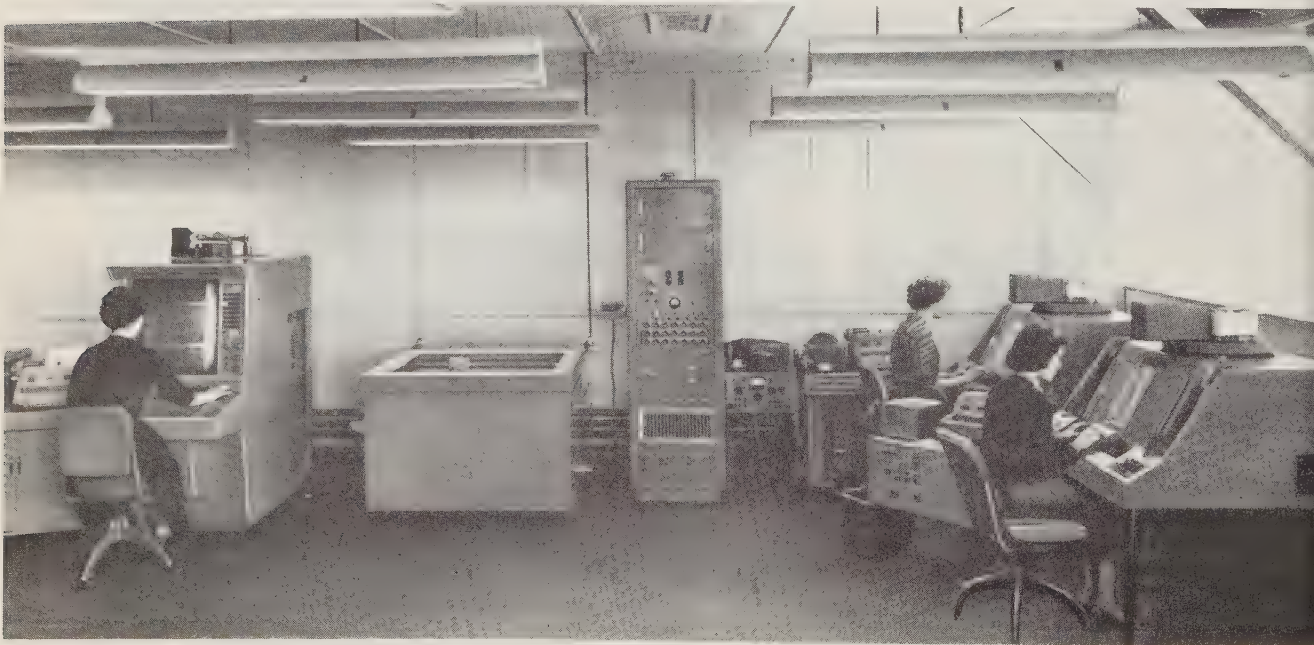
Trace readers equipped to analyze filmed records

Since costs are high—from £2,500 for a trace-reading machine and £5,500 for a medium-size plotter—a fully equipped service bureau is to be opened in Great Britain next year

THAT human beings can assimilate information from graphical displays more readily than from a list of numbers is appreciated quite as much by the businessman as by the engineer. However, when accurate detailed information is required from a graph, the task of measuring ordinates and converting them into the appropriate units can be tedious, to say the least. It is, of course, equally laborious preparing a graph from a table of numbers.

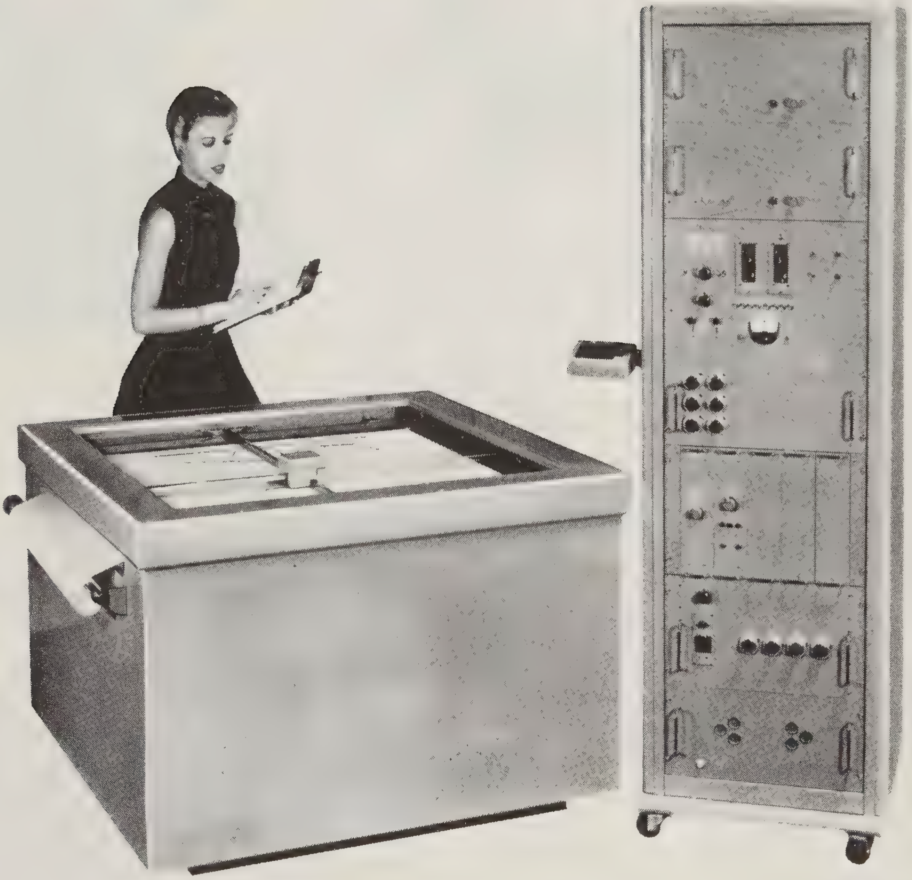
Two machines designed to do these jobs automatically are the trace reader and the plotting machine. Although both have been in existence for some time, in this country only the engineering industries have made use of them; in the main they have been employed for analyzing the results obtained from test flights of aircraft and trials of guided missiles and rockets. However, with the increasing application of electronic digital computers to business

Blackburn and General Aircraft Limited have an extensive installation of automatic reading and plotting machines



and vice-versa

The Electroplotter model H plots from 40 to 60 points a minute automatically



and industrial work, it is likely that both types of machine will be incorporated in comprehensive data processing installations of the future. The advantages of employing such machines are, of course, that the conversions are performed faster, accurately and entirely automatically.

One company that has specialized in the design and manufacture of these machines is the Benson-Lehner Corporation of the United States. Their British subsidiary* has installed a number of these systems during the past two years and a range of machines is now in production at a new factory in Southampton.

The purpose of the plotting machine is to convert a list of numbers into a series of points through which a graph can be drawn. Machines of this type can be completely automatic in operation if the data are presented in a form that can be read mechanically or electronically, such as punched cards, punched tape or magnetic tape.

A typical plotting machine made by Benson-Lehner is the Electroplotter model H. Data may be entered by punched card, punched tape or keyboard. Numbers containing four digits are handled and points can be positioned within an area 30 inches by 30 inches. Points are plotted by printing a symbol such as a full stop or a star.

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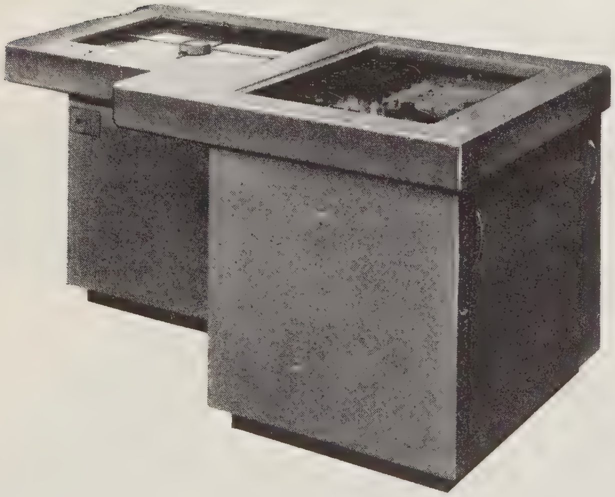
*Benson-Lehner (G.B.) Ltd., West Quay Road, Southampton.

These are positioned on the paper to an accuracy of a hundredth of an inch. Facilities are also available for altering the scale at which data are plotted.

The plotting machine consists of three major units: the reader, which is a standard punched card or punched tape unit; a control cabinet containing the decoding circuits to which is also fitted the keyboard used for entering data manually; and the actual plotting table. Paper supply and take-up reels are situated on the right and left of the horizontal surface of the table. Two bars, arranged at right angles to each other, span the table and carry the plotting head at their intersection.

The paper, usually graph paper, is positioned so that three printed marks on the paper coincide with three illuminated datum marks on the table. Vacuum holds the paper on the table. Next, the punched cards detailing all the points to be plotted are stacked in the hopper of the reading unit. When the "start" button is pressed the cards are read in turn, one at a time, and the individual points are plotted automatically and in sequence.

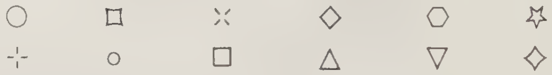
As a range of 12 symbols can be printed by the plotting head, it is possible to lay out several different curves at the same time. The actual symbol to be printed is selected automatically from data entered on the punched card. Between 40 and 60 points can be plotted per minute. An extra and unusual feature of the model H machine is its ability to draw straight lines between consecutive points. For this a simple computing circuit is included in the control cabinet and the plotting head is fitted with a pen in place of the symbol printing wheel. About 15 lines can be drawn per minute from data read from punched cards or tape—these lines positioned to an accuracy of one hundredth of an inch.



Positions of points can be entered on a keyboard or read from punched cards or tape by the Electroplotter model E

Graphs of stepped form can be prepared quickly on this machine. Such graphs are used widely for recording variations in stock level and similar administrative control data. In fact, the plotting machines can prepare the wide range of charts used to present business statistics as easily as the engineering test results that have been their main work to date.

Cost of the model H Electroplotter ranges from £5,500 upwards. A smaller plotting machine is also built, the model E, and a larger machine, the model S. Line drawing facilities, however, are not provided on these latter two machines.

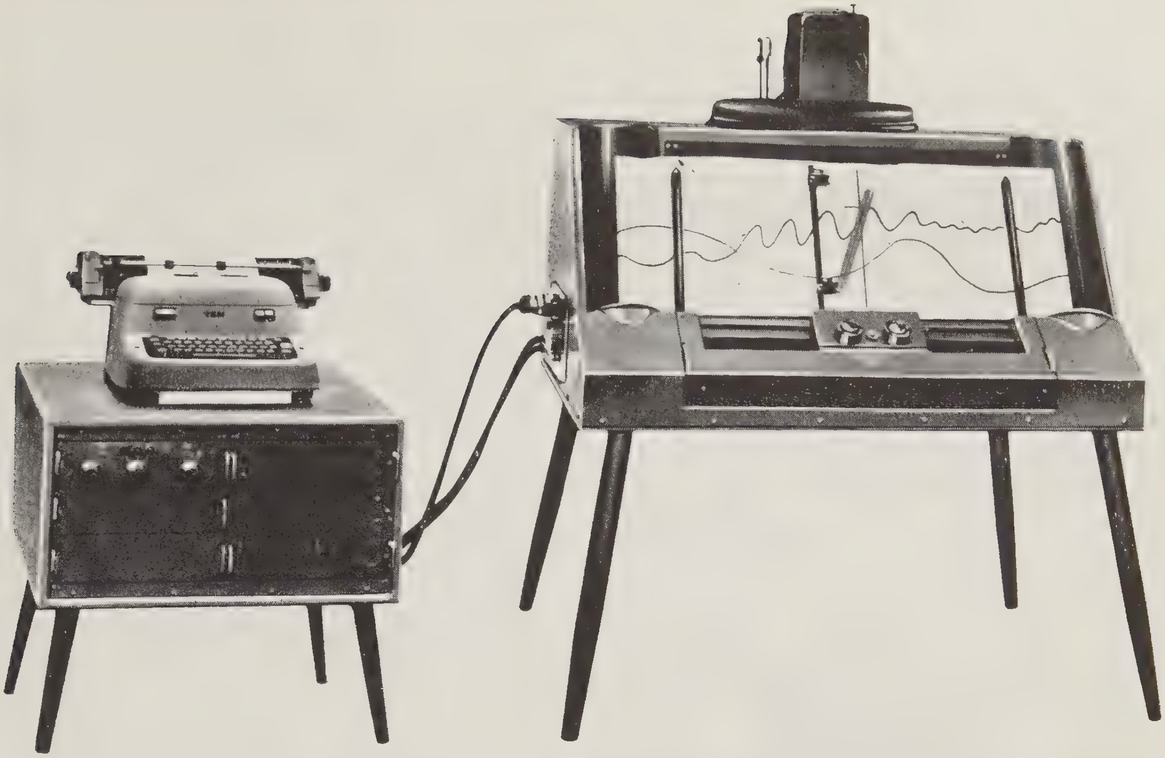


The plotting head can print a range of twelve symbols

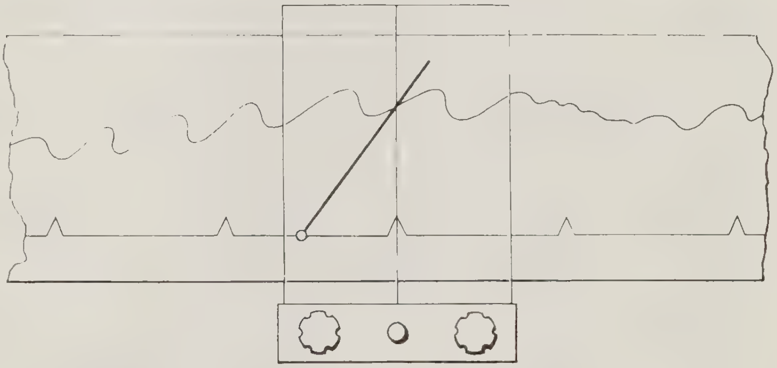
Typical of the machines designed to perform the graph-to-figures conversion task is the Oscar model J. This consists of a desk at which the operator sits and on which the trace recording is displayed, a control console that includes decoding circuits, and an output recording unit—generally an electric typewriter, though it may be a card punch or paper tape punch. The holder containing the record to be analyzed is fitted on one side of the machine and the paper record is drawn across the display panel and attached to the take-up spool. The display panel is of frosted glass and is illuminated from behind. On the model J machine this panel provides a viewing area 13 inches high by 26 inches wide.

A transparent screen, attached to a carriage, can be moved horizontally across the record. This screen has a vertical black reference line engraved on it. Also superimposed on the screen is a pivoted scale engraved with another black reference line. Both of these are controlled by handwheels rotated by the operator.

It can be seen from the illustration that, if the pivoted scale is set at an angle to the horizontal and is moved horizontally while the screen remains stationary, the point of intersection



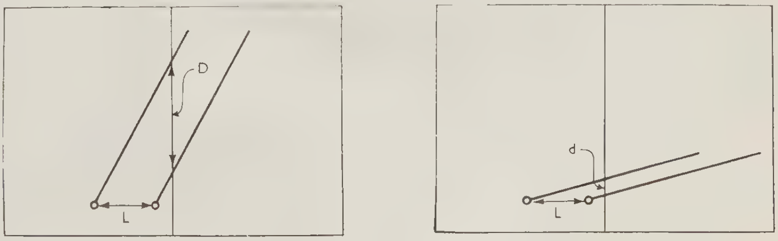
Accurate readings can be obtained from graphs using the Oscar model J automatic reading machine



A reading is made by adjusting the hand controls so that the two reference lines intersect over the trace. When the "read" button is depressed the value will be printed out automatically

between the two engraved lines will move vertically. In this way the vertical displacement of the trace can be measured.

There are four main reasons why this arrangement is used in contrast with the more obvious one of moving the scale vertically across the record. The first is the accuracy of the readings. It will be realized that if the scale is set at a shallow angle, near to the horizontal, for each complete revolution of the handwheel the reference point formed by the intersection of the two engraved lines will only move through a small vertical distance. But should the ruler scale be set at a more nearly upright angle, the reference point will move through a large vertical distance for each complete revolution of the handwheel. This is shown in the accompanying illustration.



Maximum accuracy of reading is obtained when the movement of the reference point made by the intersection of the two engraved lines just covers the displacement of the trace. If the scale is displaced through, say, the distance L, the reference point travels further when the scale is set as shown in the diagram on the left than when set as on the right

The highest degree of accuracy is obtained when one complete revolution of the handwheel moves the reference point through a vertical distance that just, but only just, covers the peaks and troughs of the trace that is being read. Thus the ruler scale would be set to a shallow angle for a trace recording which varied only slightly and at a steep angle where the variation was large.

A second reason why both the scale and the screen are arranged to move horizontally is the ease with which the datum or zero point can be altered.

Thirdly, replacing the scale with a larger version engraved with several lines permits more than one trace to be read while the screen is set at one position.

Fourthly, with this arrangement it is possible to read traces that are not plotted to a linear scale. By engraving a curved line of appropriate shape, non-linear traces can be read and the correct numerical values obtained.

Operation

To make a series of readings the operator first positions on the display panel the record to be analyzed. Along the bottom of each record is marked a datum line from which all displacements of the trace have to be measured. The operator aligns the machine with the datum on the record by adjusting two knurled discs.

Next, by rotating the control wheel on the left, the operator moves the travelling screen horizontally across the record until the position is reached at which a reading is required. Rotation of the other control wheel moves the ruler scale and allows the operator to adjust the vertical position of the point of intersection of the two lines until the latter coincides with the trace to be read. All the operator has to do now is to press a "read" button situated between the two control wheels, and the value of the ordinate is automatically signalled to the decoding circuits and printed out by the typewriter or punched into a card or tape. The reading of the ordinate values from the graph is thus automatic, the only manual work needed being to align the record with the machine at the start and to position the reference lines over the trace at each position a measurement is required.

Conversion of the measured displacement into an electrical signal is effected by a coded disc that is connected to the handwheel drive. On the disc are 12 annular tracks arranged concentrically. Each consists of a pattern of electrical conductive and non-conductive segments. Twelve brushes, one for each track, make electrical contact with the segments. The coded signal transmitted to the decoding circuit will depend, obviously, upon the pattern of conducting segments under the line of brushes at the time the "read" button is depressed.

By these means, ordinate data can be read to an accuracy of 1 part in 1,000 of the greatest scale deflection of the particular trace. This is better—in many cases very much better—than the accuracy of the trace recording itself.

Multiple readings

If several traces are superimposed on the same record, readings can be made of each in sequence—this with the screen set at the same position—and the results typed in separate columns by the output typewriter. Up to six different traces can be dealt with in this manner on the model J machine.

The machine is also equipped with a mechanical counter which records the number of positions along the record at which readings have been taken. Data that have to be included on the printed records for the purposes of identification are entered manually on a keyboard provided on the right-hand side of the desk.

This same model can also be equipped to analyze filmed records. Each frame of the film is projected on to the frosted glass display panel from behind and the readings are made in the usual way. Any film between 16 mm. and 89 mm. in width can be projected.

An operator can make an average of 1,000 recordings an hour using the Oscar model J. For short periods and on suitable records, readings have been taken at the rate of one per second. Such trace-reading machines cost from £2,500 upwards depending upon the number of additional features required.

Ciné film reader

Another Benson-Lehner reading machine is called the Boscar and is designed solely for reading ciné film. This has a viewing screen measuring 21 inches by 21 inches and is provided with a pair of crosswires that can be positioned manually to coincide with any point on the image. Each wire is connected to a coded disc; as before, the reading is made automatically when the "read" button is depressed and the result typed or punched into cards or tape.

Although ciné readings can be made to an accuracy of 1 part in 10,000 of the screen height and width, a more usual order of accuracy, after allowing for photographic distortion and similar effects, is 1 in 5,000. Readings can be made at the rate of 1,000 points per hour and 16 mm., 35 mm. and 70 mm. ciné film can be projected.

Plotting machines and trace readers provide an essential auxiliary service for centralized computing groups by accelerating the rate at which raw input data can be prepared for the computer and also converting output data into a more assimilable form. What is especially valuable is that these machines improve communication between the users and the computer. They are, however, expensive to buy and a considerable flow of data is needed before they can be employed economically. For this reason Benson-Lehner consider that organizations possessing limited facilities might wish to hire trace reading and plotting equipment on a time basis. Accordingly the company is planning to establish next year the first service of this kind in Great Britain.

Designed to project ciné film, the Boscar model N-2 has a viewing screen 21 inches square

Controlling production by computer

Since August, 1958, a computer has been planning the production of a factory employing 500 people. The stock of work in progress has been significantly reduced, the burden of administration has been lightened and morale and productivity have improved. Results have been so encouraging that similar methods are about to be applied to two larger factories.
What adds piquancy to the situation is that the firm concerned is International Computers and Tabulators, Ltd., who have been taking—and proving—their own medicine

Since August 11th, 1958, the manufacturing schedule of a small factory engaged on batch production work has been controlled by a computer. All the documentation needed for the operation is automatically produced either by the computer or associated punched card machinery.

It would not, of course, be correct to imply that the machine makes all the necessary decisions, but, given the basic data, the computer produces statements indicating what is to be manufactured, when work is to be started and whether a given production target will overload the factory or, if not, what spare capacity will be available. In addition, effective control is exercised over production. Should some parts not be produced in the required quantities, this fact is immediately noted and the production plan automatically modified so that the deficiency is made up. Supervisory management in the factory still has the responsibility of implementing the production programme and also making those decisions that are beyond the scope of the computer.

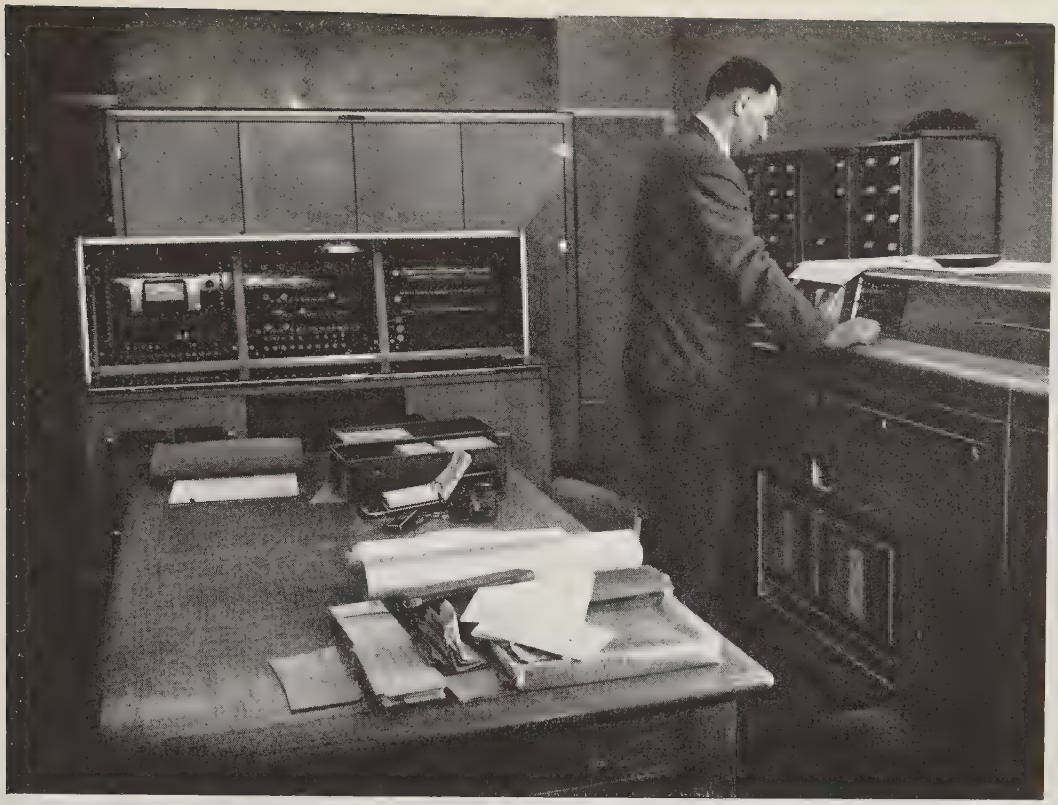
The factory operated in this manner is the Hollerith 1B factory, at Letchworth, in Hertfordshire. This is now part of the International Computers and Tabulators, Limited's organization.

Since this work has been performed on a computer, many advantages have accrued and a number of lessons have been learned. Production has been brought under positive control. The high priority shortage list has disappeared, because potential shortages are detected before they occur. Work in progress has been reduced by an appreciable amount. At the present time no hard figure of money saved can be given, because the project is still in its formative period, but merely to walk round the factory is sufficient to suggest that work in progress has been considerably reduced: storage racks and benches are noticeably free from the clutter and congestion usually associated with batch production.

Because of the air of spaciousness that has been provided at this small factory, and because everything that is made is passed on immediately to other workshops, a sense of purpose has been given to work performed. As a result, morale has improved and productivity, in many cases, increased.

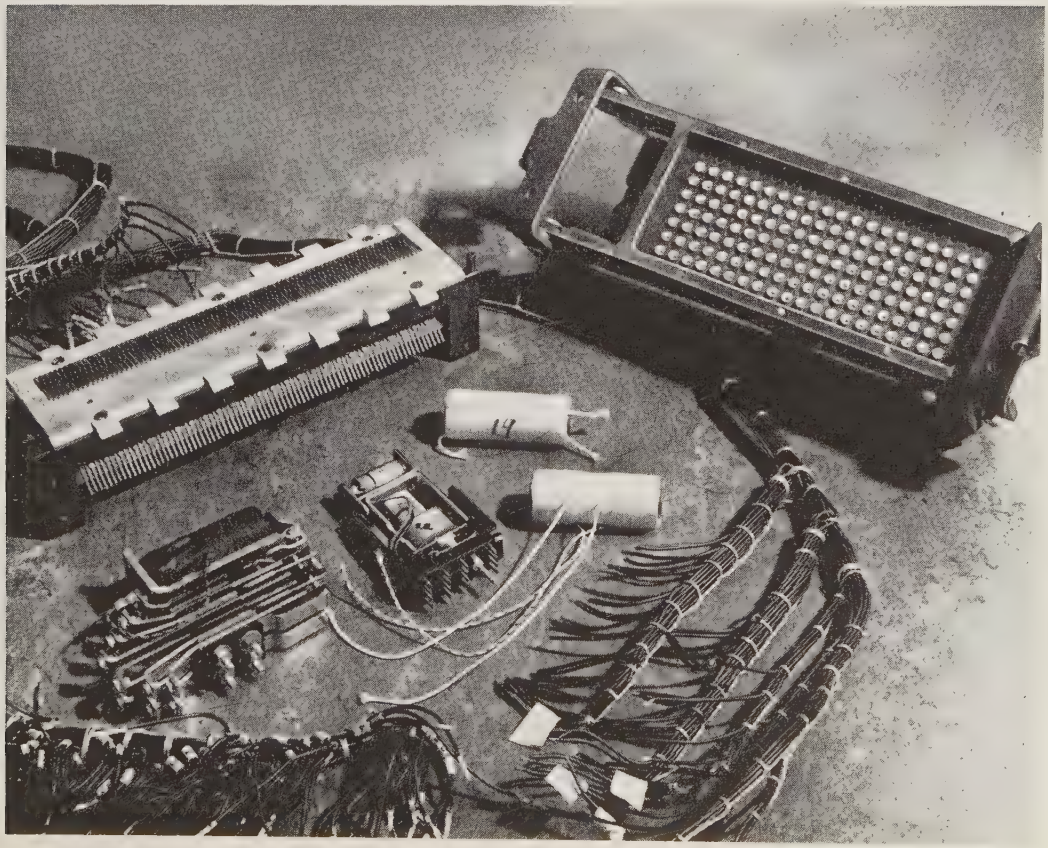
Shop-floor supervision has benefited because, production now being planned in the true sense of the word, all items are being manufactured in balanced quantities. Foremen are no longer harried by progress-chasers seeking parts in short supply. Consequently, foremen are able to concentrate on their job of getting the best out of the men and machines under their command. Similar benefits are experienced by the remainder of the factory production management. For them the load has been lightened because the day-to-day detail work is performed automatically. Exceptions to the production plan are brought to their notice only when decisions outside the scope of the computer system are required.

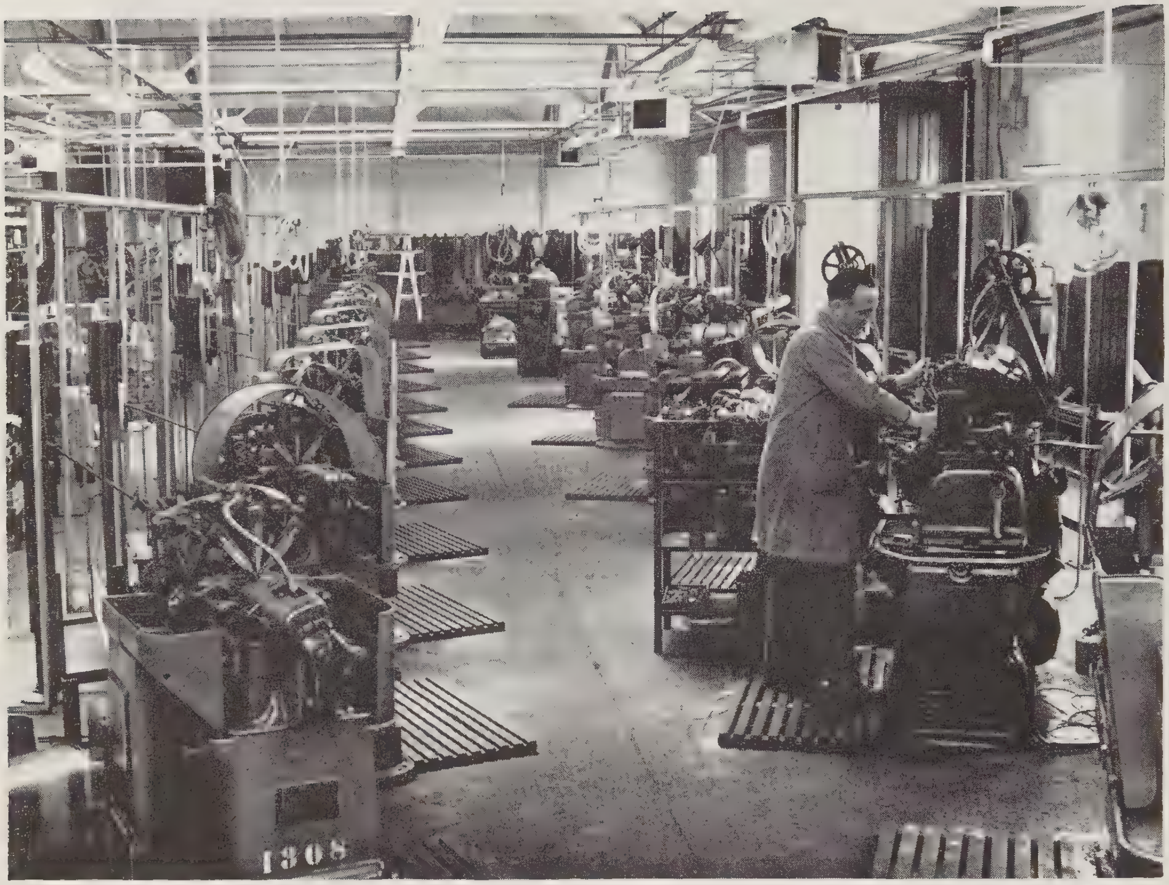
Administration is so much easier that fewer people are required. No one has been displaced as a consequence of the work being transferred to the computer—staff savings were not the main



A Hollerith type 1201 *electronic computer is used to process the production control data. This machine is fitted with a magnetic drum that has a storage capacity of* 1,024 *computer words*

Typical range of items produced at the 1*B factory of International Computers and Tabulators, Limited. At the top right is a plugboard, to the left a brush slide assembly and below coils relays and cable harnesses*





Two lines of automatic machine-tools. For the purpose of production planning, machine-tools are arranged in production groups. Work allocated to a group can be performed on any machine within the group

object—but where normal wastage has reduced departments below the numbers previously employed, personnel have not been replaced.

All this is very commendable, but, as is the nature of things, it was not achieved without a good deal of trouble and effort. One of the assumptions made in the beginning that proved to be false was that the transition period would last four months, by which time all jobs proceeding through the factory under the old scheme would have been cleared. But, in addition to this not being so, it was found that during the transition period the burden on the existing production supervision was greatly increased because even small quantities of parts still passing through the factory under the old scheme prevented the successful and smooth adoption of the new system.

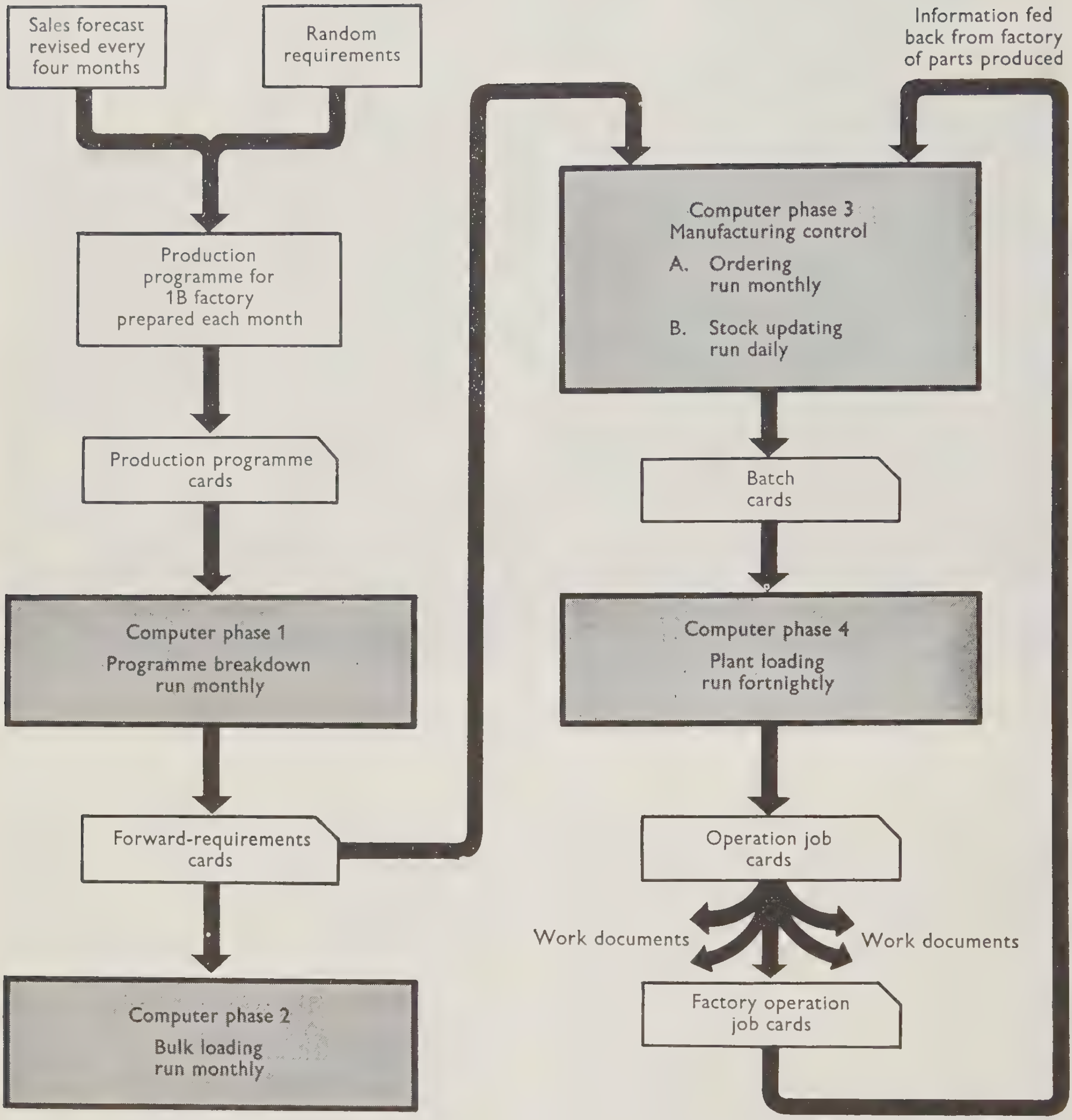
Another source of trouble, easily foreseen, but difficult to avoid, was to get everyone to operate the system correctly from the start. Before the system was introduced, all the production supervisors from charge-hands upwards, including shop stewards, attended a series of lectures at which the aims and objects were fully explained and also how the system would work when applied to their sections of the factory.

To accustom the shop supervision to the paper work involved, the operation of the factory was simulated. This was done by gathering all the people concerned round a table and issuing them with the documents produced by the computer that authorized their sections to perform jobs. Then, on the basis that the jobs had been completed, the workshop supervisors filled in the appropriate details and returned the documents. These data were then processed in the computer as they would be under actual running conditions, and revised factory documents issued to the supervisors. However, in spite of all this painstaking training, experience showed that insufficient

Coil winding and finishing. Again for planning purposes, teams of operators are arranged in groups. Nine groups are employed in the 1B factory on the assembly of light electro-mechanical components

time was spent on putting those concerned in the picture. One of the most important facts that had to be learnt by factory supervision was the need to return documents promptly. Under the old production control system, speed in returning documents was not imperative, because control and planning were not so precise. Production in these circumstances usually centres round the shortage list, and proceeds from crisis to crisis; consequently, planning documents are not considered to be important.

In contrast, with a computer-controlled system it is essential that information concerning achievement is fed back promptly so that the progress of the work and fulfilment of the plan can be accurately measured. For instance, if machinery breaks down or the scrap rate increases suddenly, such information must be transmitted back to the computer so that due allowance can be made and any necessary changes in the production programme carried out. A story may be told to illustrate the improvement in utilization that can easily be achieved. The class of machine-tools called "automatics" are generally regarded as expensive machines to run, and consequently not the type to be left idle. In view of this, it was the practice that, when these machines completed an order, rather than leave them unused, raw material was drawn from stores and units surplus to requirements were produced for stock. As a result, it was discovered that during the course of time certain parts had been manufactured in such large numbers that a stock sufficient for several years had been built up. This situation was not appreciated until the work of transferring the job to the computer was undertaken. Now, of course, machine-tools that will not be fully employed are notified to production management and work can be transferred to the 1B factory from other factories or withdrawn from subcontractors.


Sales forecast revised every four months
Random requirements
Production programme for 1B factory prepared each month
Production programme cards
Computer phase 1
Programme breakdown run monthly
Forward-requirements cards
Computer phase 2
Bulk loading run monthly
Information fed back from factory of parts produced
Computer phase 3
Manufacturing control
A. Ordering run monthly
B. Stock updating run daily
Batch cards
Computer phase 4
Plant loading run fortnightly
Operation job cards
Work documents
Work documents
Factory operation job cards

Flow of data through the four computer phases. Control is exercised over production by continually comparing the achievement of the factory with the plan. Information of parts made is fed back from the factory and included in the daily stock updating run

So much for the results obtained. The factory to which the computer-controlled production scheme was applied is small; it employs about 500 people, mostly female, of whom 380 are engaged directly on production work. Light electrical assemblies are made, such as cable harnesses, coils, relays, plugboards and plugboard wires. All these are produced in batches that may contain from 5 to 50,000 items. The most complicated article takes about 10 weeks to manufacture and the simplest a week.

Within the factory the productive effort is divided into 47 machine-tool groups and nine assembly groups. A machine-tool group may contain one or more machine-tools. The criterion is that it shall be possible to do a job allocated to a group on any of the machines within that group. In somewhat similar fashion, teams of girls are organized into assembly groups.

All the information needed for production control is prepared on an early design of computer, the Hollerith type 1201 machine. This is similar to the more recent Hollerith 1202 machine, which has already been described briefly in Data Processing,* except that it is equipped with an information store of smaller capacity—a magnetic drum of 1,024 words capacity instead of 4,096.

Production control sequence

Production control is divided into four main phases involving five separate runs on the computer. Briefly, the data processing sequence is as follows:—

From the overall production programme specified by the management, the programme for the 1B factory is derived and the first task of the computer is to produce a statement of all the parts that will be required to fulfil this latter programme. This first computer run is called the "programme breakdown" and is performed once a month.

The second computer phase is the "bulk loading" run. During this run the computer will calculate whether the implementation of the new programme will cause too much work, or too little, to be placed on the factory. This programme is also run once a month.

After it has been confirmed that the work can be done by the factory, the next step is to convert the list of parts required into manufacturing orders. This is the purpose of the third computer phase of the data processing sequence.

Two separate computer runs are performed, one monthly and the other daily. Each month the new manufacturing orders required for the new production plan are created. And each day the computer updates the figures of stock held.

Controlling production

The reason why the second programme is performed more frequently is because it is the actual procedure by which control is maintained over production. Information of parts made is fed back from the workshops and, with the present manufacturing achievements taken into account, an accurate assessment of any additional orders that must be issued to implement the current production plan can be made. If a data processing system can be said to possess a heart, then this phase is the heart of the production control operation, where the word "control" is used in its true sense.

The fourth and final computer phase is performed fortnightly and allocates to the various production groups the work arising from the new manufacturing orders. Information derived specifies when work on a particular operation is to be started, and when it is to be completed. This phase is known as "plant loading."

Finally, the appropriate works documents are produced and issued. As the work is completed, information is fed back into the data processing sequence so that due account can be taken of the fulfilment of the overall production programme.

Changing the production plan

It has been implied that the four computer phases are performed at various fixed intervals. This is not necessarily so. If, owing to external causes, it is necessary to modify the production plan, any or all of the computer phases can be run to discover what changes are required. And, because the computer can process data so rapidly, it is possible to compile a new production schedule within a matter of hours of the new data being made available. This ability to rearrange a complex plan at short notice is one of the principal advantages possessed by a computer-controlled scheme.

In normal circumstances, however, it is likely that the time interval between the various runs will lengthen. It has been found that, as the production of a factory is brought under true

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*"A Review of Electronic Digital Computers," page 32, *Data Processing*, January-March, 1959.

Keypunching data into cards. Punched cards are used to introduce data into the computer

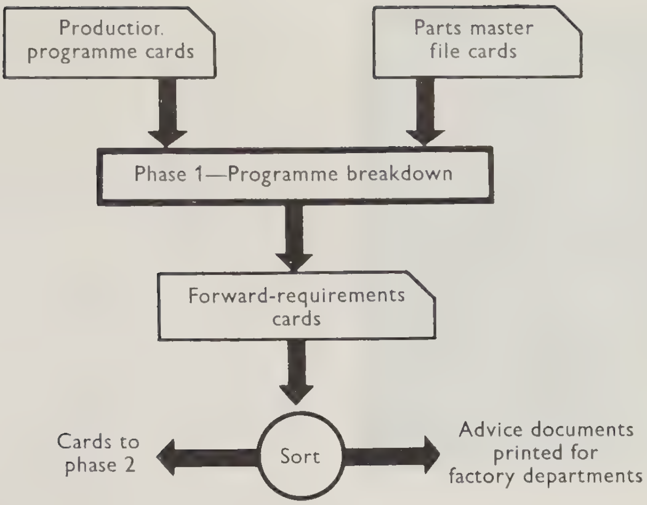
control, the need for sudden variations is obviated, and consequently production plans do not need to be revised so frequently.

Another feature of this method of production control is that the figures give a picture of the manufacturing situation that will exist in the future—this based on the actual production achieved to date. It is these data concerning the future that are so valuable to management.

Basically, the effectiveness of any production plan depends upon the accuracy with which future sales can be estimated. The initial data are therefore derived from the sales side. An estimate is given of the items that need to be built in the next 21 months. These 21 months are divided into 22 time periods of varying length and the production required of each item during each period is specified. The 22 time periods are made up as follows: each week of the first 12 weeks, each month of the succeeding nine months and, finally, one period that covers the last nine months. The production programme is revised and re-issued by management once every four months.

Although the production plan is created from this basic information, provision has to be made for the supply of items at random intervals. For example, the demand for spare parts to maintain existing equipment can never be known precisely, so an estimate is given; this, of course, can and, possibly, must be revised more frequently than once every four months.

Data obtained from these two sources are coalesced and a printed document, the 1B production programme, is compiled once a month. These data are punched into cards to form the 1B production programme file. One card is punched for each item manufactured by the factory. Into this are punched the numbers required of each product for each of the time periods listed in the production programme. For the purposes of this article, a completed

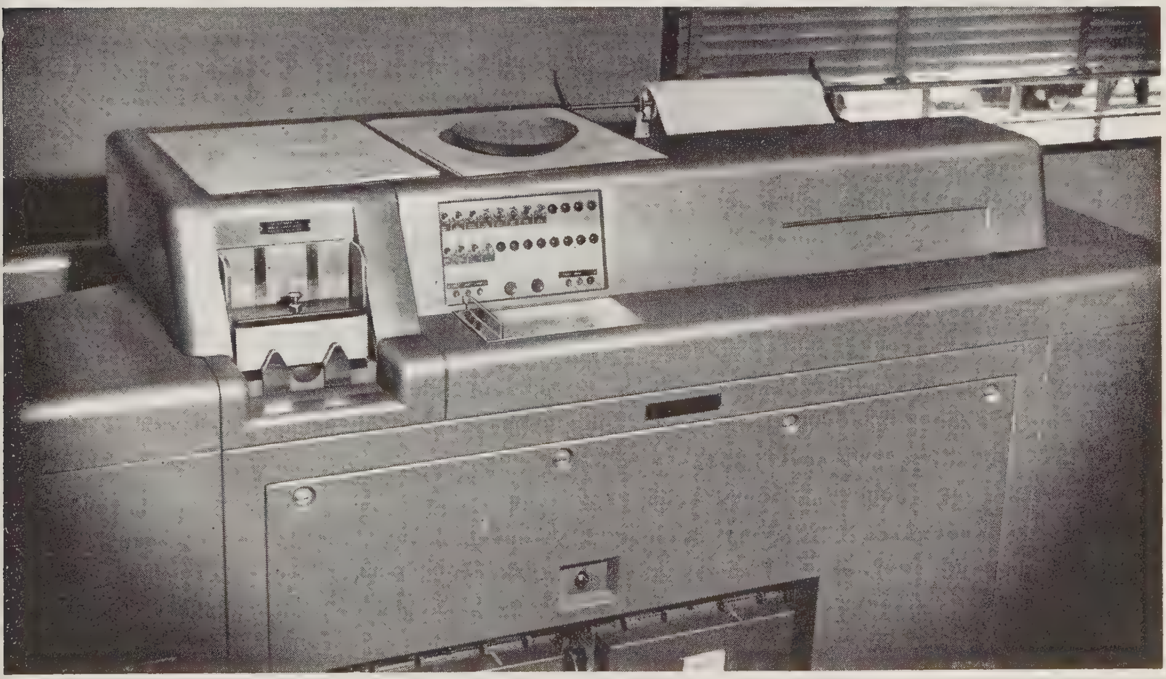

Production programme cards
Parts master file cards
Phase 1—Programme breakdown
Forward-requirements cards
Cards to phase 2
Sort
Advice documents printed for factory departments

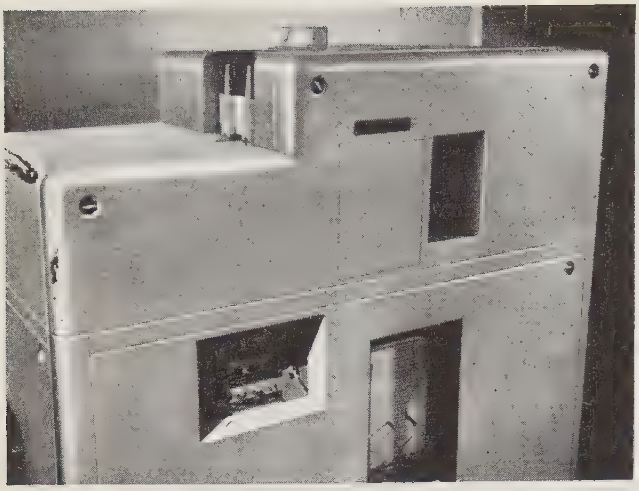
In phase 1, *items specified in the production programme are translated into parts required*

end product manufactured by the factory is called an item, and an individual piece that is assembled with others to make an end product, or item, is called a part.

The production programme cards provide the basic data needed for the first computer phase—the programme breakdown. The object of this phase is to convert the production programme listed in terms of items into a production programme in terms of parts. This is done for each of the time periods of the forecast. In order to be able to perform this work, the computer is provided with additional data that specify the parts required for each item. These permanent data are contained in a collection of punched cards known as the parts master file.

Input output unit connected to the computer. On the left is the punched card reader and on the right the printer





Data to be carried forward to other data processing phases are punched directly into cards by this automatic unit connected to the computer

One master file card is created for each part manufactured by the 1B factory. On each is noted the items that use the particular part and also the numbers required. This method of recording constructional information is contrary to normal practice; it is more usual for one card to represent the final item, and on the card would be entered all parts that are needed. The inverse method is adopted in this case because of the nature of the products manufactured in the 1B factory. Many different types of item are made from relatively few basic parts. As a very rough indication, approximately 1,000 separate items are assembled from 2,000 parts. Handling the data in this way means that the time required to perform the programme breakdown on the computer is kept to a minimum.

As a result of this first computation, a pack of punched cards is produced giving future requirements. These cards are referred to as forward-requirements cards and one is punched for each type of part. Data recorded on each card are the quantities of each part needed in each of the time periods of the production programme. In addition, the category of the part is given and the raw material from which it is made.

Category indicates whether the part is purchased, supplied by another factory within the I.C.T. organization, subcontracted or manufactured within the 1B factory.

Next, the pack of forward-requirement cards is sorted into categories. Those relating to parts to be manufactured in the 1B factory are passed on to the next computer phase. Those in all the other categories are fed through a tabulator and documents printed to advise other departments of forthcoming requirements. For example, the purchasing department is provided with two of these printed documents. One lists parts to be purchased from external manufacturers and the other gives the raw materials that will be needed by the factory. In a similar manner, the subcontract department is notified of new orders that will have to be placed with their suppliers.

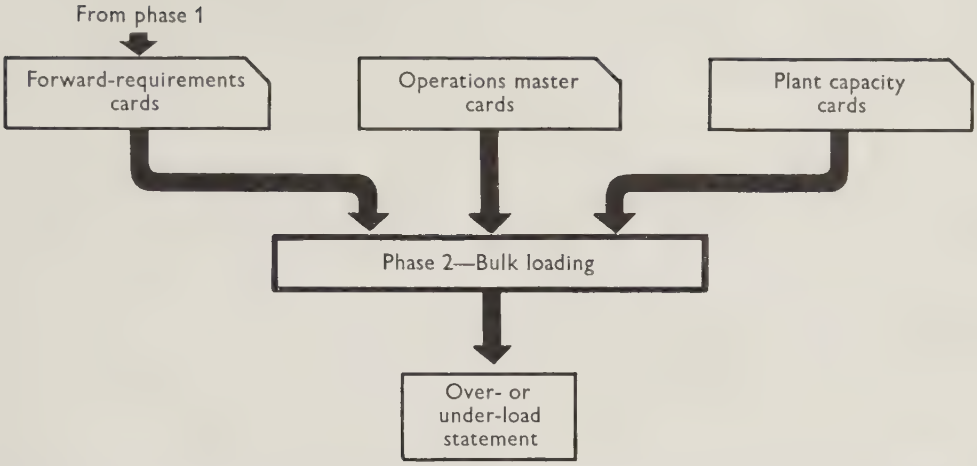
Now it is necessary to determine if sufficient manufacturing capacity is available within the 1B factory to make those parts for which it is responsible. This second computer phase is apart from the main data processing sequence. Its sole purpose is to give production management an extended view of manufacturing requirements that will be needed in the future.

Before this sequence is considered in greater detail the point must be stressed that the new production programme has to be superimposed on previous programmes for which the factory is still producing parts. Also, the new programme must take into account how far the factory has succeeded in completing these previous programmes.

Data for the second computer phase, known as the bulk loading operation, are read from the forward-requirement cards. In addition, operations master cards provide information on the working hours required by the various machine-tool and assembly groups to manufacture each type of part. Also, data specifying manufacturing capacity engaged in fulfilling previous production programmes are supplied to the computer from a file of punched cards recording capacity already allocated.

A direct comparison is then made by the computer of the manufacturing hours needed to complete the new programme and the hours available. From this, a printed over- or under-load statement is produced that shows, for each of the time periods, which machine-tool and assembly groups will have too much work to do and which will not have enough. As a result, the production management can decide what action should be taken. This phase is run once a month or whenever the manufacturing capacity of the factory is altered.

So much for what might be termed the long-term planning arrangements. The next two computer phases—the third and the fourth—are concerned with the day-to-day running of the factory. It has already been mentioned that the third computer phase, known as manu-

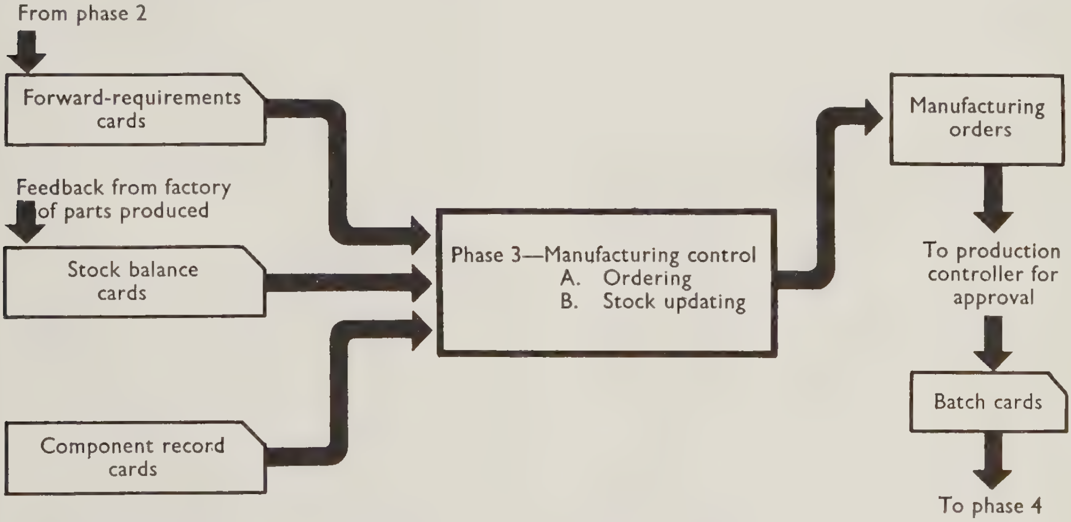


The ability of the factory to fulfil the new production programme is assessed during the bulk loading phase

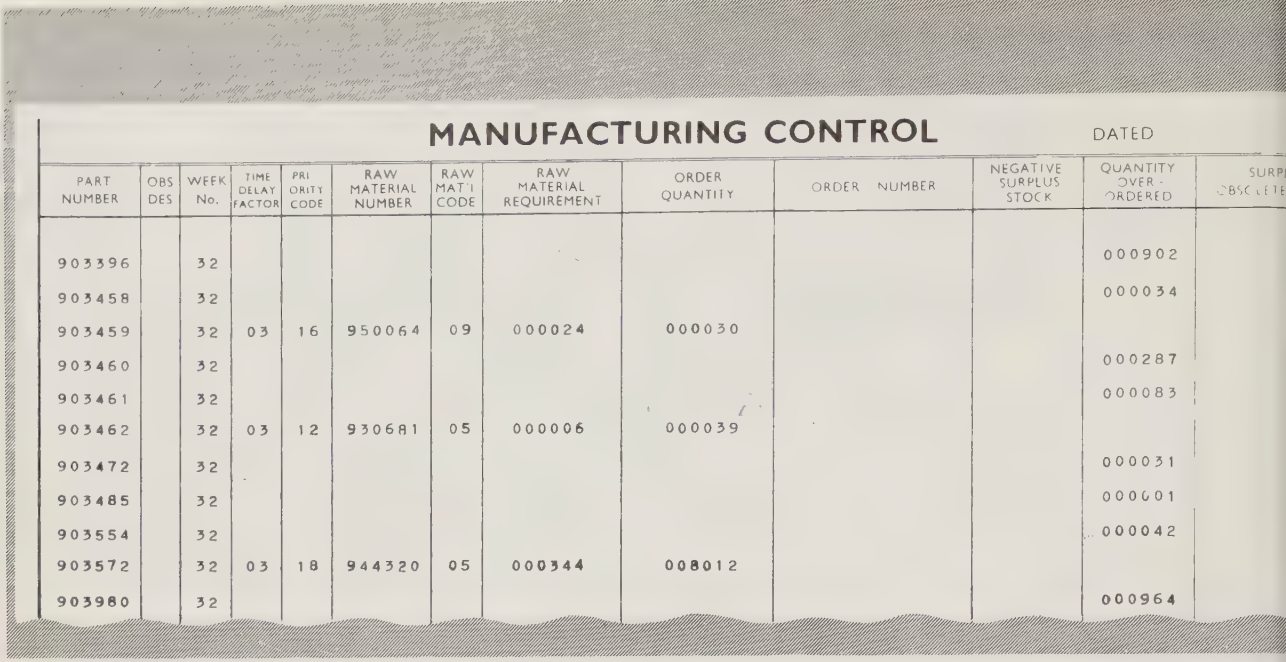
facturing control, consists of two separate computer runs—one performed monthly and the other daily. The purpose of the monthly run is to create new manufacturing orders to meet the needs of the new monthly production programme.

Basic data for this computation are provided by the forward-requirements cards that were used during the second phase. However, in this case, only information concerning production requirements for the next 20 weeks are read from the cards. Information from a file of stock balance cards is also supplied to the computer. On these cards is entered the actual stock balance for each part plus the stock that will exist for 20 weeks in the future if all the existing production programmes are completed.

Other necessary data for this phase are provided by a file of component record cards. Each part is represented by one card and among the information recorded is the maximum and minimum number of parts that are to be included in one production batch. Obviously it is not a good thing to order exactly the number of parts for which there is a definite requirement, as it might be uneconomic to set up a machine-


From phase 2
Forward-requirements cards
Feedback from factory of parts produced
Stock balance cards
Component record cards
Phase 3—Manufacturing control
A. Ordering
B. Stock updating
Manufacturing orders
To production controller for approval
Batch cards
To phase 4

New manufacturing orders for the production programme are produced during phase 3. Also new orders may be prepared to rectify shortages that could occur owing to underproduction or because of sudden demands for spares



MANUFACTURING CONTROL DATED

PART NUMBER	OBS DES	WEEK No.	TIME DELAY FACTOR	PRI ORITY CODE	RAW MATERIAL NUMBER	RAW MAT'L CODE	RAW MATERIAL REQUIREMENT	ORDER QUANTITY	ORDER NUMBER	NEGATIVE SURPLUS STOCK	QUANTITY OVER-ORDERED	SURP OBSOLETE
903396		32									000902	
903458		32									000034	
903459		32	03	16	950064	09	000024	000030				
903460		32									000287	
903461		32									000083	
903462		32	03	12	930681	05	000006	000039				
903472		32									000031	
903485		32									000601	
903554		32									000042	
903572		32	03	18	944320	05	000344	008012				
903980		32									000964	

Portion of a document printed during the manufacturing control phase showing the stock and order position for various parts during a particular week

tool to produce only one or two parts. Therefore, a maximum and minimum batch size is specified and, when a manufacturing order is made out, a batch size between these limits will be given. Any parts produced additional to requirements are, of course, held in stock and will be taken into account when the manufacturing orders for the next monthly production programme are being prepared.

New orders

From all this data the computer calculates what new manufacturing orders should be issued to cover the requirements of the new production programme, taking into account existing stocks of parts held and parts that will be available shortly as previous programmes are completed. New orders are printed and sent to the production controller for approval.

The portion of the phase three computer run that is performed daily adjusts the values recorded on the stock balance cards to include those parts that have just been completed by the factory. In addition, the stock position for the next 20 weeks is recomputed.

Undoubtedly, the most important feature of this phase is the daily feedback of information from the factory workshops. It is this which enables the manufacturing operation to be controlled. For instance, should a machine-tool break down completely or develop a fault which results in an abnormally high percentage of scrap being produced, information about the resulting under-production of parts would reach the computer within 24 hours. And when the daily stock updating is performed, the difference between the number of the particular part that should have been produced and the number actually produced will be noted. If this condition could result in a significant shortage of parts at a future date, a new manufacturing order to make up the deficit will automatically be issued. If, however, the detected shortage only affects the stock held because the part was being manufactured surplus to immediate requirements anyway, then no action will be taken.

Random orders

Because the stock figures are updated each day, the planning system can cope with sudden random demands for parts—for spares, say. If the parts are issued, a stock deficit, that will occur at some time in the future, will be detected by the computer during the daily run and a new manufacturing order will be issued automatically to rectify the position.

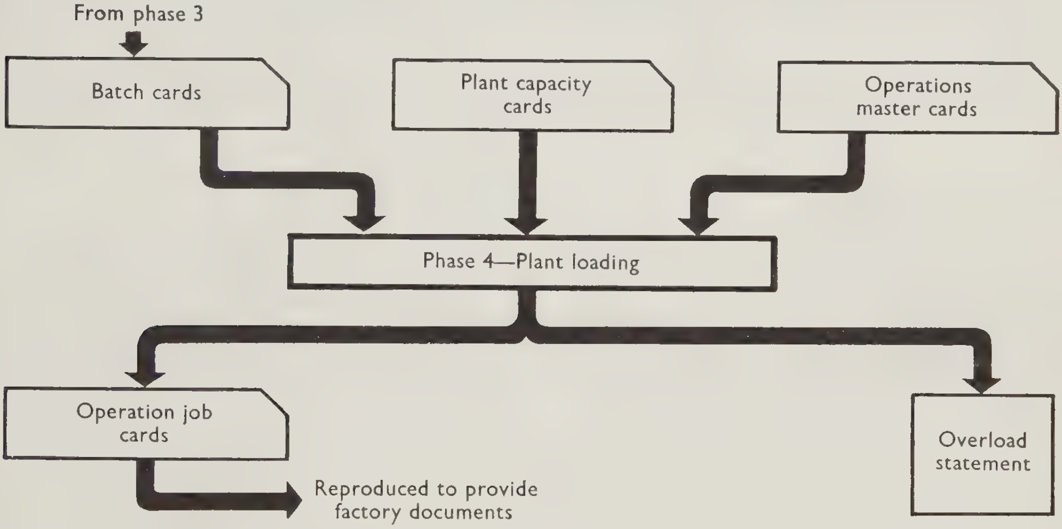
In situations such as these the computer is making managerial decisions and the value of using it for this type of work is that such decisions are made quickly and consistently and take into account many more variables than the human brain could cope with in the short space of time available.

After the production controller has agreed to the manufacturing orders produced by the computer, the data are punched into a pack of cards called batch cards. These are then fed into the next daily stock updating run so that, before any new manufacturing orders are created, full account will be taken of those orders just authorized.

Following this phase, the new orders that have to be manufactured will be known. In the fourth and final computer phase—plant loading—the object is to dovetail these new manufacturing orders relative to the existing orders, allocating the work to the various production groups within the 1B factory in such a fashion that each batch of parts will be completed by the date specified on the batch card.

New production requirements, as specified on the batch cards, are entered into the computer. These are then converted into working hours needed by the various production groups to perform the manufacturing operations. Basic data giving the times and operations to be performed are obtained from the punched cards of the operations master file. These cards are the ones that were used in the bulk loading phase. Data from the cards of the plant capacity file that specify production capacity already allocated are also entered into the Hollerith 1201 computer.

The computer now has to solve a problem that is in some respects similar to a jigsaw. New jobs have to be allocated to production groups so that they do not interfere with work already allocated. In addition, each job must be completed by the week recorded on the batch card. To achieve this, some form of priority has to be arranged. Priority for tackling jobs is determined by combining the week during which the work is to be completed with the total time it takes to make the part. The computer then picks the job with the highest priority and selects the last manufacturing operation. Next, it searches through the work allocated to the particular production group required for this operation until it finds sufficient unallocated hours in which the new work can be performed. Having settled this, the computer selects the last but one operation and searches through the work allocated to the appropriate production group until a gap of the required length is found. This gap must, of course, be selected to precede the week during which the final production operation is due to be started.



Work, represented by new manufacturing orders, is allocated to the various production groups within the factory during phase 4*—the plant loading run*

Proceeding backwards from the completion dates, the computer fits each new job into the factory working schedule until all the new work has been apportioned. Loading the work on the factory in this way means that maximum utilization is obtained of both machines and labour.

Should there be no capacity available to perform certain production operations, an overload statement is printed. Overloads on certain production groups within the factory are bound to occur from time to time, in spite of the fact that this was not indicated by the bulk loading phase. The sequence of the manufacturing operations required on the various parts is not considered during bulk loading, only the gross manufacturing capacity available. Consequently temporary overloads can occur when several jobs require the services of the same machine-tool, or assembly group, at the same time and this condition will only be shown up during the plant-loading phase.

Operation job cards

At the end of the plant-loading sequence, operation job cards are punched and the plant capacity cards are updated with the latest information. Operation job cards for the next 12 weeks are produced. Each card refers to one production batch and includes data stating when each manufacturing operation is to start and when it is to be completed. As a natural outcome of this, statements are produced giving the residual capacities available for each machine-tool or assembly group. These are sent to the production controller and, because the information refers to conditions that will exist in the factory at some future date, he can arrange—all being well—to obtain extra work of the appropriate kind.

This concludes the planning of future production and now all that remains is to produce the necessary work documents from the operation cards. Documents for the next two weeks only are produced. It is not worth printing work documents for the remaining 10 weeks, because minor corrections to the production programme will be coming through at frequent intervals.

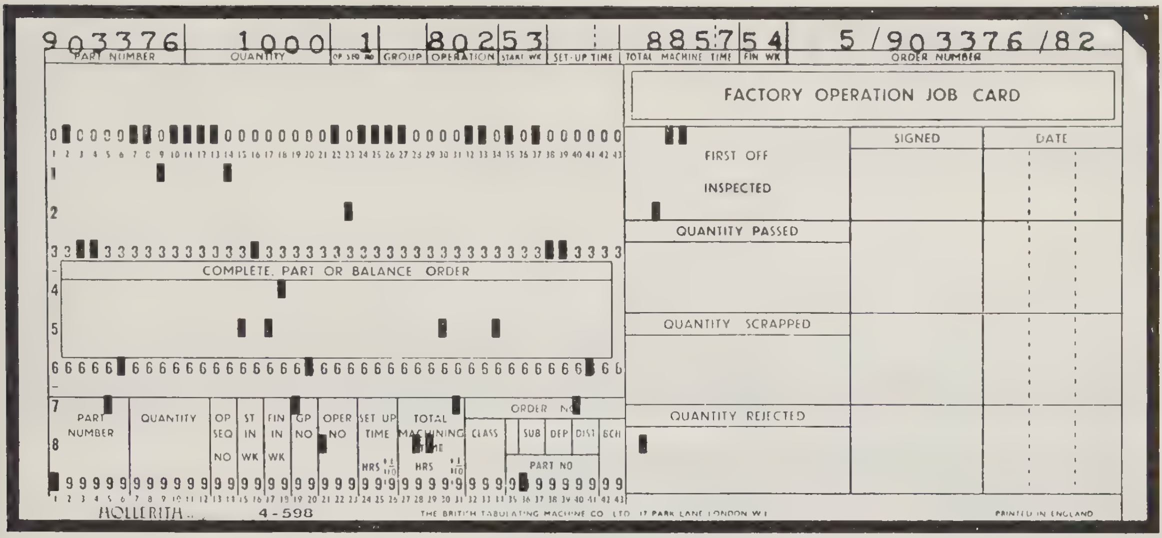
From the operation job cards the first documents prepared are advice lists that are sent to the various departments within the factory so that the latter may marshal all the tools, materials and drawings that will be needed. These documents are made available to the departments concerned one clear week before the parts are due to be manufactured.

Next, data on each job card are reproduced automatically into eight different punched cards for use as factory documents. Data recorded on each card are also printed along the top edge. Thus these cards can be read by both men and punched card machines. The eight types are:—batch identity card, material requisition card, drawing requisition card, central control operation job card, factory operation job card, labour card, goods made card and part requisition card. Except for the first two, all these cards are sent to a central control office during the week preceding manufacture. Central control is an office located within the factory that administers the transfer of information between the factory and the computer section.

One of the eight factory cards—the factory operation job card—is the authority to manufacture. A pack of these cards, covering one week's operations, is given to the foreman shortly before manufacture is due to begin. At the same time, central control issue the other cards to the appropriate people; the labour card goes to the time clerk, the drawing requisition goes to the drawing stores, and so on.

The foreman instructs the operator to perform the work and hands him the factory operations job card. When the work is completed the parts are sent for inspection accompanied by the job card. Numbers of parts accepted by the inspector and numbers scrapped are recorded in writing on the card, which is then returned to central control. Any numerical difference between the number of parts that should have been made and the number of parts actually made is marked in a special area on the central control job card. Completed cards are then returned by central control to the computer section and these cards provide the essential feedback information necessary in maintaining control over manufacture.

Before describing what happens to these job cards, something must be said about the responsibilities of the foreman. The plant-loading phase allocates work to be done by the various production units in weekly amounts. The actual sequence in which this work is tackled and which operators will perform this work is decided by the foreman concerned. Consequently, the foreman is still responsible for the day-to-day running of his department. Before the operation job cards can be used for entering data into the computer, the information recorded as pencil marks must be converted into



PART NUMBER	QUANTITY	OP SEQ NO	GROUP	OPERATION	START WK	SET-UP TIME	TOTAL MACHINE TIME	FIN WK	ORDER NUMBER
903376	1000	1	8	02	53		8857	54	5/903376/82

FACTORY OPERATION JOB CARD

	SIGNED	DATE
FIRST OFF INSPECTED		
QUANTITY PASSED		
QUANTITY SCRAPPED		
QUANTITY REJECTED		

COMPLETE, PART OR BALANCE ORDER

PART NUMBER | QUANTITY | OP SEQ NO | ST IN WK | FIN IN WK | GP NO | OPER NO | SET UP TIME HRS 1/10 | TOTAL MACHINING TIME HRS 1/10 | ORDER NO: CLASS | SUB | DEP | DIST | BCH | PART NO

HOLLERITH 4-598 THE BRITISH TABULATING MACHINE CO LTD 17 PARK LANE LONDON W 1 PRINTED IN ENGLAND

Factory operation job cards provide the authority to manufacture and specify the quantity of a particular part to be made. Shortly before manufacture, a pack of these cards covering one week's production is handed to the foreman

punched holes. A special item of punched card machinery—a mark-sensing punch—performs this operation. As the cards are fed through the machine, the pencil marks are sensed electrically and the information they represent is punched into the cards.

At weekly intervals a list is printed giving the difference between the number of parts actually produced and number of parts scheduled for production—in other words, the exceptions to the production programme are listed so that production management can investigate the causes and take appropriate action.

Other data processing sequences

Other punched cards are completed and returned to central control when the work has been inspected and cleared. For instance, the time clerk returns a completed labour card which is forwarded, in turn, to the accounts department for bonus and other payments to be assessed.

It will be realized that the sequence just described only covers the main theme of the production control procedure. Many other types of document are produced and many other data processing sequences are performed. However, the way in which an electronic computer can be used for this work has been indicated together with the advantages that this gives. Undoubtedly, the most important feature of the entire sequence is the way in which information on actual production achieved by the factory is immediately fed back into the data processing system so that at all times account is taken of the true manufacturing situation and not of a hypothetical situation that, according to some outdated plan, should exist. This is what is really meant by control—the continuous measurement of achievement to see that it conforms with the plan and, should this not be so, the taking of automatic corrective action.

What are the next steps? Shortly, the Castlereagh factory of I.C.T. will be controlled in this way and the data processing sequence is being extended to provide control over costs as well. Later, production at the No. 1 factory at Letchworth employing 1,500 people will be administered by a similar computer-controlled system.

I.C.T. have proved to themselves that production control by computer is not only possible but highly desirable. Now that the great financial saving that can be made by reducing the stock of work in progress and making better use of men and machines has been demonstrated, what started as an exercise to gain experience in the application of computers to a thorny problem of industrial administration has become, in a very short time, a proved means of reducing production costs.

Edge-punched cards

Inexpensive system of recording data by means of slots

Particularly where information is required only intermittently, it can be inappropriate—even extremely inefficient—to employ complex automatic data processing equipment. There are nowadays various manual systems that are compact, versatile, accurate and easy to operate.

Such a system is described in the following article, which also gives details of two current applications

The punched card is such a versatile and adaptable document that it is used in many manual data processing systems as well as in the more widely known mechanical accounting systems. One particular design of punched card—the edge-punched card—has been employed in business for many years. Recently the firm of George Anson and Co., Ltd., has designed simple mechanical equipment to make easier the task of handling these cards.

As the name of these cards implies, the characteristic that distinguishes them is a series of holes punched along the four edges.

Each card represents one item, person or product, and the groups of holes spaced round the edge of the card represent certain characteristics or features which the item may possess. Data are recorded by clipping through the card so that a slot extends from certain holes to the edge of the card. Actual data recorded depend, of course, upon the meanings given to the holes.

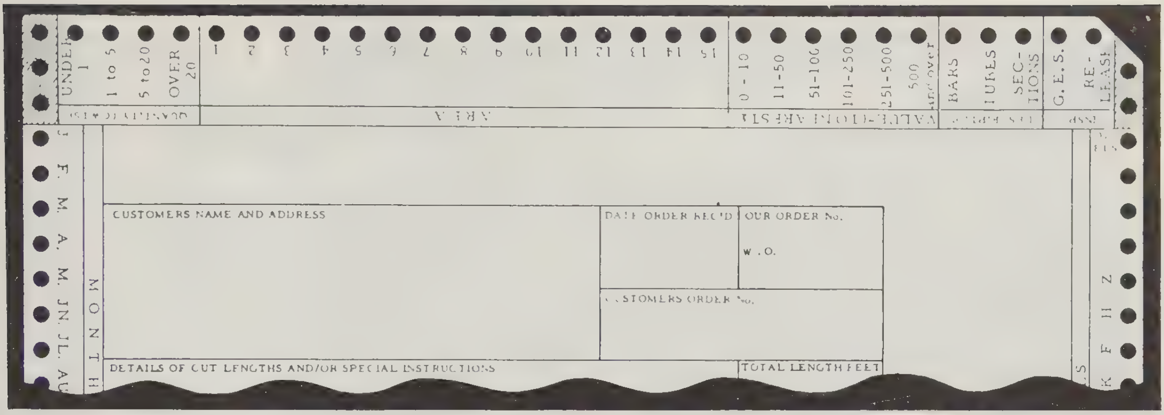
To demonstrate the principle of operation a very simple example will be given—so simple that it must not be considered as typical. Imagine that a company desires to keep records of, say, 12 designs of typewriters used in a large office block. An edge-punched card is made out for each typewriter. Along one edge of the card there will be 12 holes, one for each design. If the machine is a design identified by the letter F, then the F hole will be clipped, as shown in the illustration.

Should the typewriter service mechanic wish to find out how many typewriters of design F are in use, all that he need do is to gather the complete pack of cards together, pass a rod through the pack in the position of hole F and lift the rod. All cards that refer to typewriters of design F will then fall out of the pack because they will not be lifted by the rod, as they will have slots cut in the position of hole F.

Although this is an over-simplified explanation of the system, it does illustrate the principle. The reason that it is unrealistic is that it is not necessary to have 12 holes in order to be able to select any one of 12 items. More concise methods of recording numerical data are available. By giving a group of four holes different numerical values it is possible to record any one of the 10 decimal digits. Where the numerical values given to the four holes are 1, 2, 4 and 7, all the numbers from 0 to 9 can be recorded by clipping any one, or two, of these holes. For example, one is represented by clipping the hole marked 1; three by clipping the holes marked 1 and 2; five by clipping holes 4 and 1; six by clipping 4 and 2 and so on. Separate groups of holes are used to represent units, tens, hundreds and so on.

This 1, 2, 4, 7 code group is chosen because any decimal figure can be represented by clipping one, or at the most two, of the holes. If the more familiar binary code group (1, 2, 4, 8) were used, three holes would, of course, be needed to represent the figure seven.

In the case where the cards are to be sorted only, each digit is represented by a group of four holes. First, the rod is passed through the hole representing the least significant digit of the number, i.e. 1. All cards with numbers ending in 1 will be left behind. These are placed at the back of the pack. Incidentally, it is not necessary

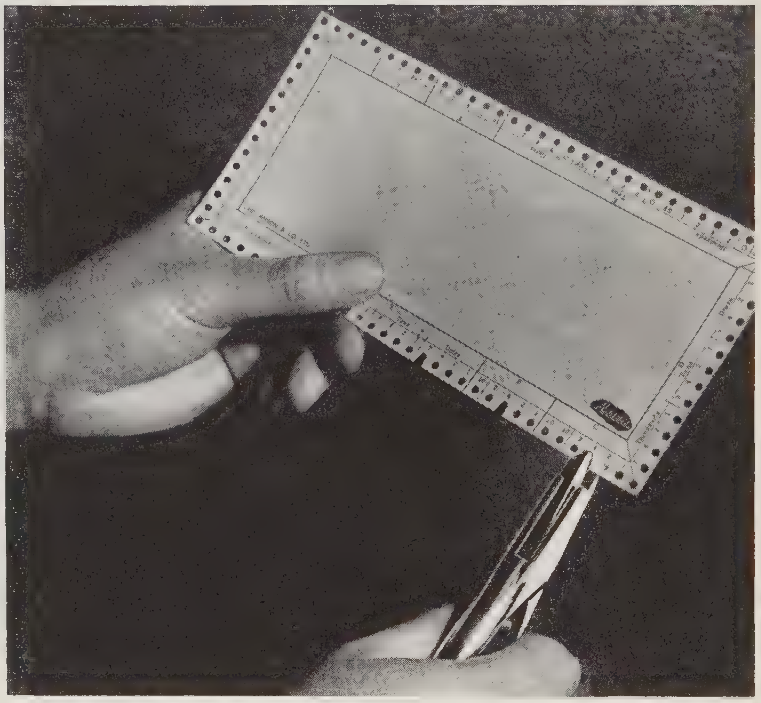

UNDER 1
1 to 5
5 to 20
OVER 20
QUANTITY (CWTS)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
AREA
0 - 10
11-50
51-100
101-250
251-500
500 and over
BARS
TUBES
SEC-TIONS
G.E.S.
RE-LEASE
J. F. M. A. M. JN. JL. AU
MONTH
CUSTOMERS NAME AND ADDRESS
DATE ORDER REC'D
OUR ORDER No.
W.O.
CUSTOMERS ORDER No.
DETAILS OF CUT LENGTHS AND/OR SPECIAL INSTRUCTIONS
TOTAL LENGTH FEET
K F H N
S

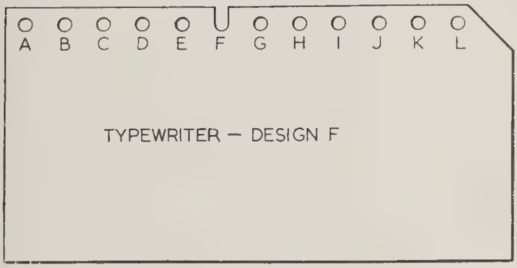
(Above) Part of an edge-punched card. Meanings given to each hole are printed alongside. Other data are typed in the central portion of the card

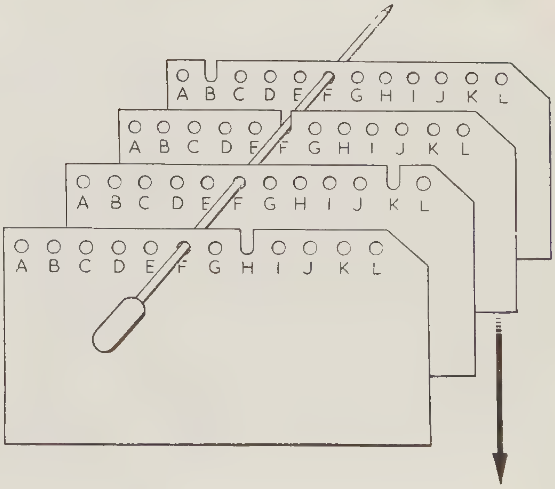
(Right) Data are recorded by clipping the card so that a slot extends from the appropriate hole to the edge

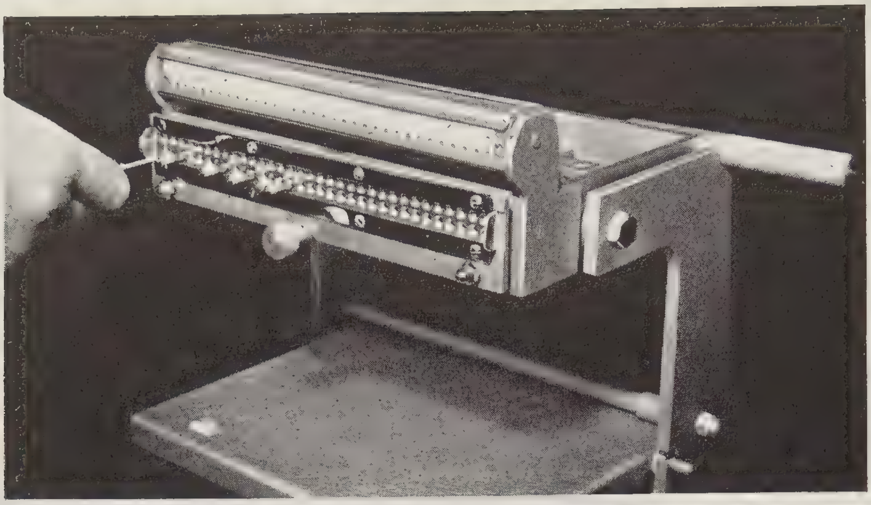
(Below) Application of edge-punched card. This card refers to a typewriter of design F, so the F hole is clipped

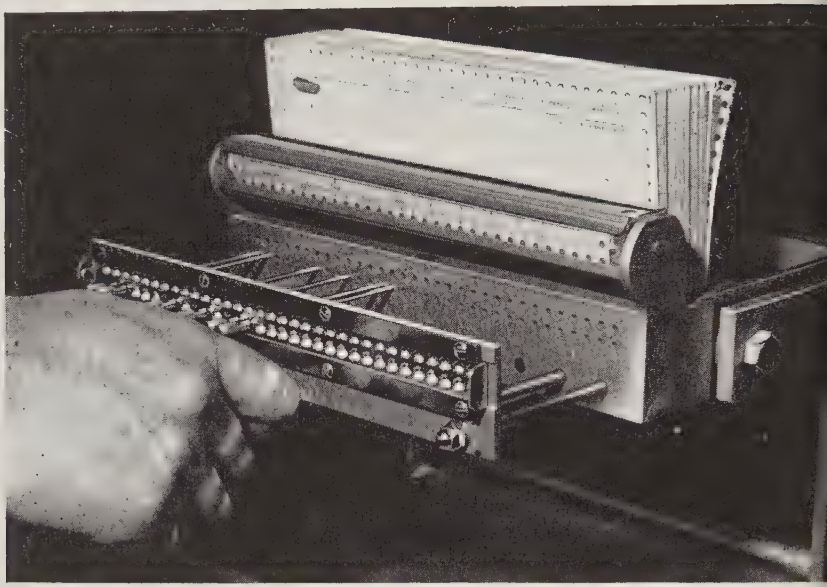
(Below right) Edge-punched cards referring to typewriters of design F can easily be selected from the remainder of the pack by passing a rod through the F hole and lifting. All cards with the F hole clipped will fall out of the pack







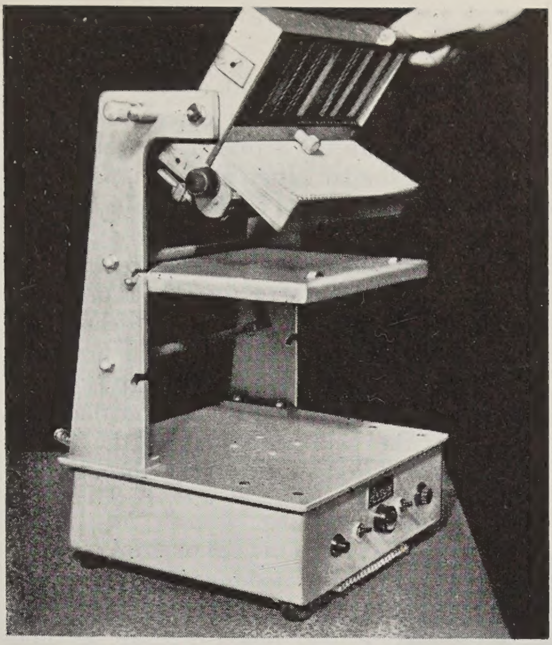


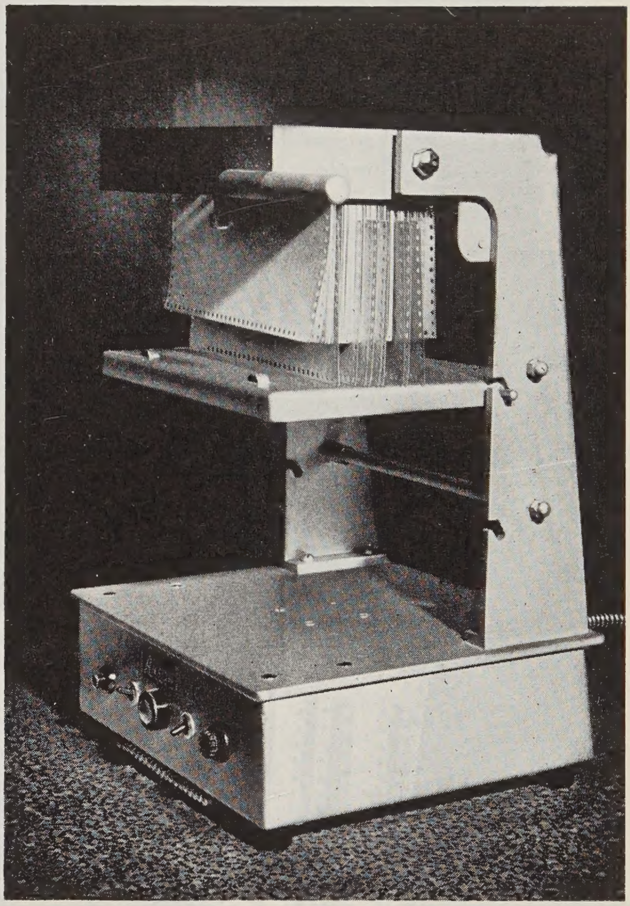


to include 0's in the sorting sequence. In fact, no provision is made to record 0 in cards used exclusively for sorting.

Next, the rod is passed through the hole representing 2. All cards left behind are again collected and placed at the back of the pack. This procedure is repeated until the highest digit in the number has been dealt with, by which time the cards will be arranged in correct numerical order.

When the purpose of the system is to enable any one card, or group of cards, to be selected from a pack, a fifth hole, marked SF, is included in each group of holes that is used to represent one digit. (The initials stand for Single Figure.) This hole is clipped every time the figure can be recorded by clipping one hole only. In other words, every time the figure is a 1, 2, 4 or 7. The figure 0, necessary with this system, is recorded by clipping holes 4 and 7. Thus no matter what figure is entered, two holes in each group will be clipped. The reason for this double punching is to avoid obtaining incorrect cards when a single number has to be selected. Consider the case where all the cards with two in the units column are to be selected. The





Sequence of events when an electrically actuated frame is used to select cards. First, rods are pushed through the appropriate holes in the frame and locked in position (opposite page, top). The holes can be identified by the edge of the card displayed immediately above them. Next (left) the locking bar is pulled forward bringing the rods with it and the pack of cards is placed in position. (Above) The bar is pushed back and the frame inverted. When the vibrator is switched on, the selected cards will fall on to the collecting table

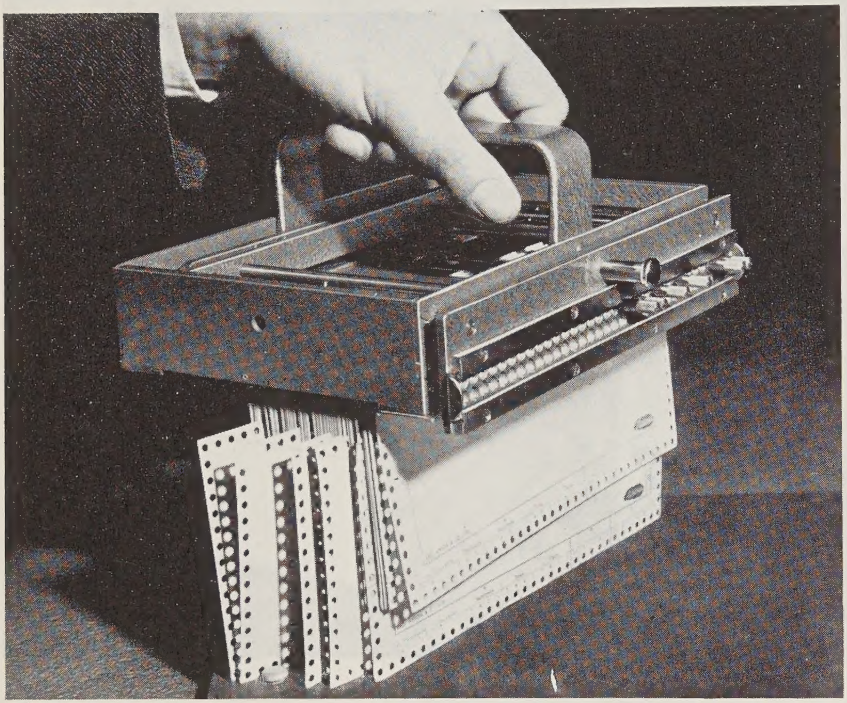
rod is passed through the pack of cards in the position of the 2 hole. When the rod is raised, all the cards that have the 2 hole clipped will be left behind. If the SF hole is not used, these cards will include not only all the cards in which the value two has been recorded, but also all cards in which the values six and nine have been entered. This is because six is represented by clipping both the 2 and 4 holes, and similarly nine is represented by clipping the 2 and 7 holes. In contrast, if the SF hole is punched and two rods are used—one passed through the position occupied by the 2 hole and the other through the SF hole—only those cards recording the value two will be free to fall out of the pack. Where numbers containing more than one figure have to be selected it is merely a matter of using more rods. As two rods are needed for each digit, six rods will be required if cards bearing the number 194 are to be selected: two for the hundreds digit, two for the tens digit and two for the units digit.

Where the card system is to be used for both sorting and selecting, a composite code is used that includes the value 0. For this purpose a sixth hole is added to each group of holes.

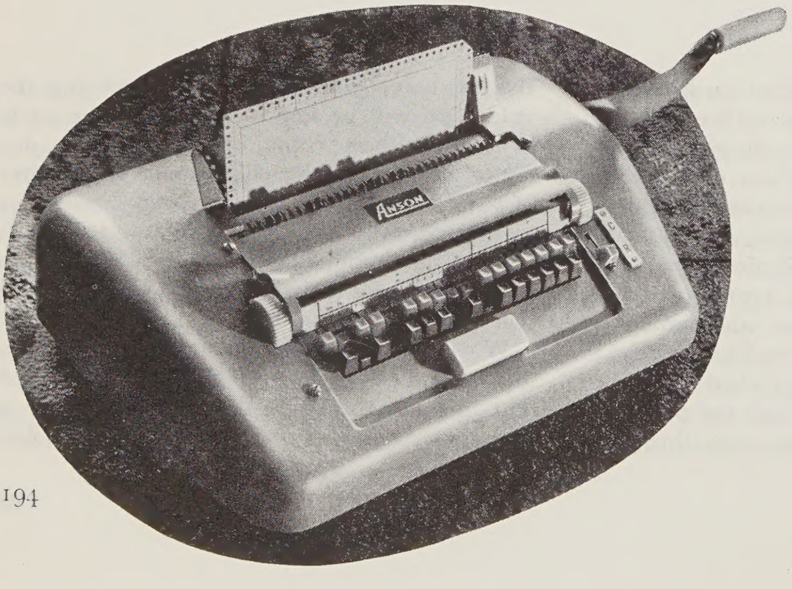
Again the double clipping rule applies: thus if the 0 hole is clipped, the SF hole has to be clipped also to conform with the rule.

Although the cards are punched on all four edges, selecting and sorting are performed, at a given time, only on data recorded along one side. Because of this, the initial design of the card must be carefully considered in order that related information may be recorded along one edge. To cater for the possibility of having to push six or even more rods through the complete pack, George Anson and Co., Ltd., have produced two simple selection frames: one is manually operated and the other is manually loaded but electrically actuated. Basically, both frames are of similar design although, naturally, the electrically actuated frame is easier to use.

As can be seen from the accompanying illustration, the manual frame is fitted with two bars through which a series of holes is drilled at the same spacing as is used on the cards. To indicate the meaning given to each hole, the edge of a card of the particular design is cut off and placed under a transparent cover that runs parallel to the perforated bars of the frame. Steel selection rods are pushed through the



Manual selection frame. A pack containing up to 500 cards can be held in the frame

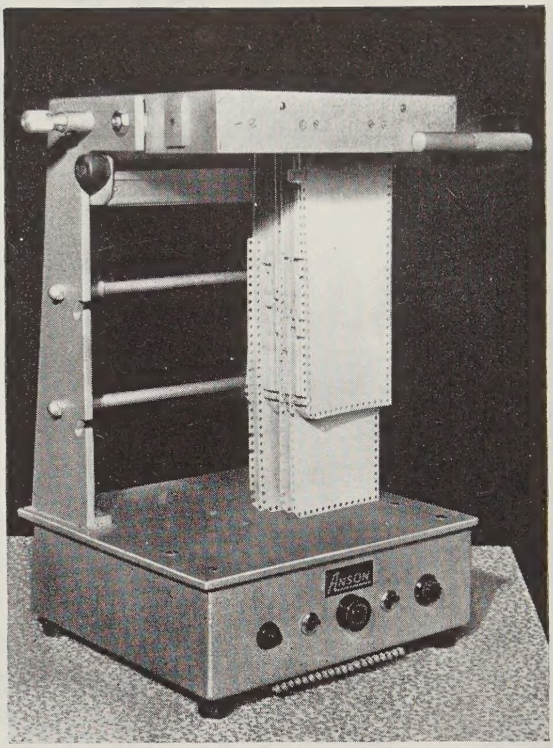


Where large numbers of cards have to be clipped, this manually operated unit is used. Data are entered by depressing the appropriate keys and the slots are clipped when the lever on the right is depressed appropriate holes in the frame and secured in position in the front bar by a locking device. Next, the front bar is pulled forward, bringing with it all the selection rods. The punched cards are stacked on edge in the frame and the front bar is pushed back causing the selection rods to pass through the holes in the pack of cards. The frame is then inverted and shaken, when the required cards will fall out.

With the electrically actuated frame, selection rods are positioned in the manner already described and the frame, which is pivoted on a fixed base, is then inverted. When a button is pressed an electric vibrator causes all the required cards to fall out on to a collecting tray. If considerable numbers of cards have to be handled in the course of a day, the electrically actuated frame is highly desirable because it is much less fatiguing to operate. From four to five hundred cards can be loaded at one time into either type of frame.

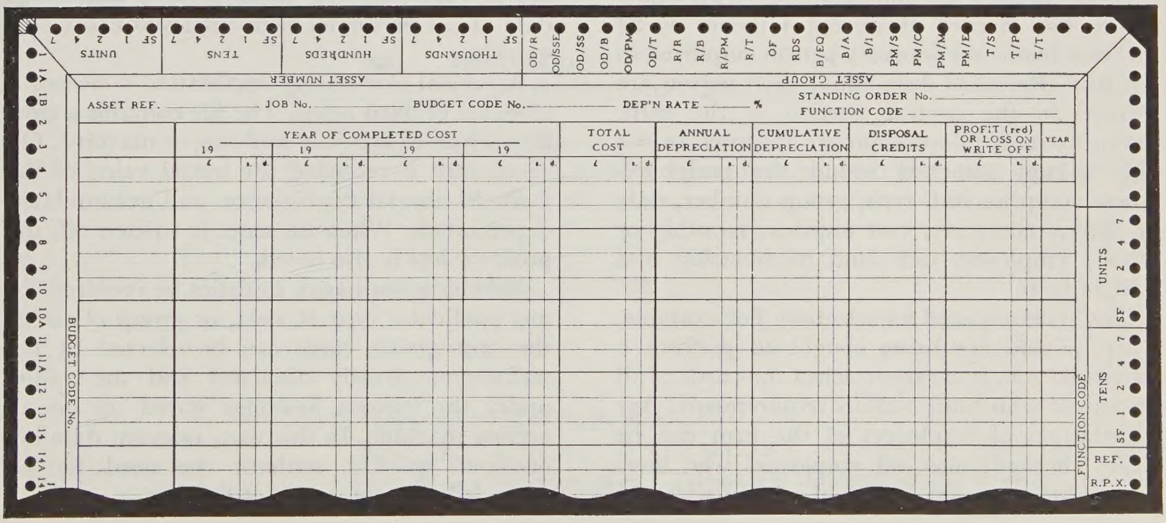
Size of cards

Both frames can accept cards whose edges do not exceed $11\frac{3}{4}$ inches. Actually there is no standard size for an edge-punched card. Normally the choice depends solely upon the amount of information that has to be recorded. And because only one edge can be used at a time, the shape of the card is not important—it may be square or rectangular. The only dimension that must remain constant is the space between holes in order that the same equipment can handle all designs of card.



Selecting and sorting are performed on one edge at a time. Consequently, the layout of the card must be carefully arranged so that related data are recorded along the same edge. Here the cards are being selected from data recorded along the short edge

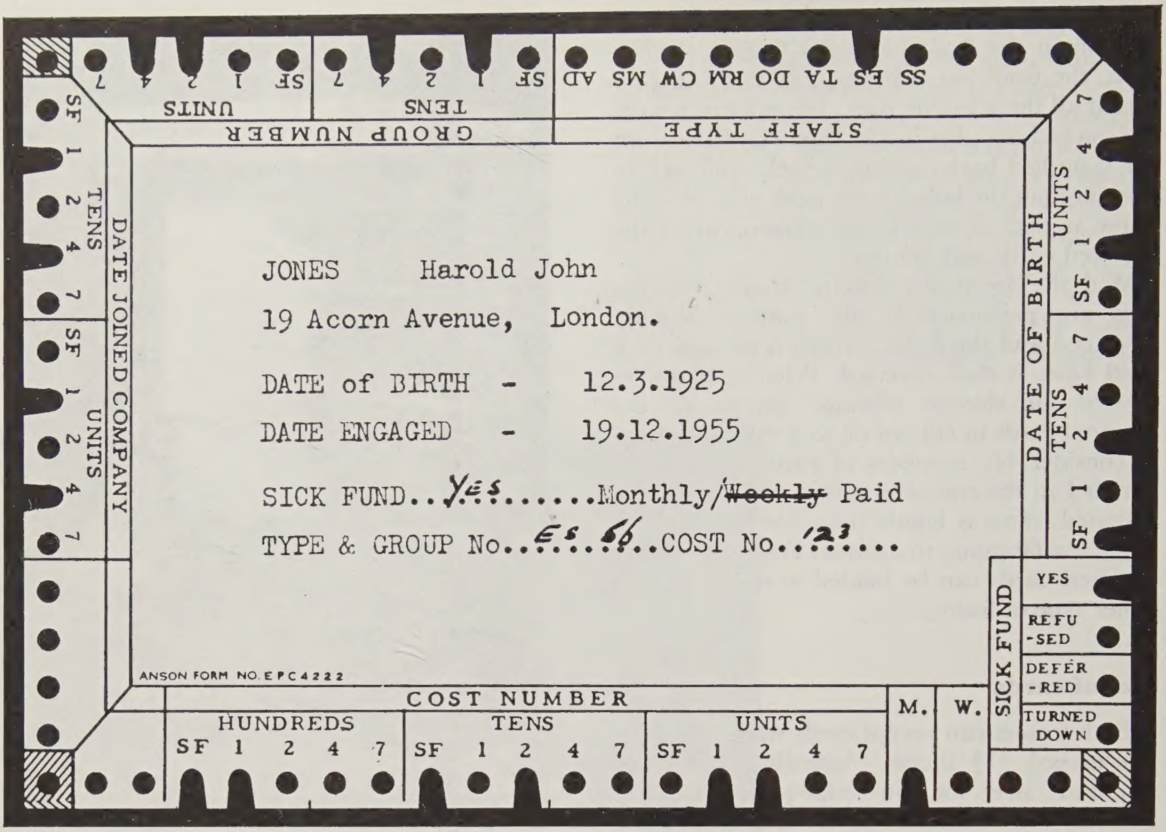
Part of an edge-punched card used to record the value and depreciation of fixed assets


SF 1 2 4 7
UNITS
TENS
HUNDREDS
THOUSANDS
ASSET NUMBER
OD/R
OD/SSE
OD/SS
OD/B
OD/PM
OD/T
R/R
R/B
R/PM
R/T
OF
RDS
B/EQ
B/A
B/1
PM/S
PM/C
PM/M
PM/E
T/S
T/P
T/T
ASSET GROUP
1 1A 1B 2 3 4 5 6 8 9 10 10A 11 11A 12 13 14 14A
BUDGET CODE No.
FUNCTION CODE
UNITS
TENS
REF.
R.P.X.

ASSET REF. ________ JOB No. ________ BUDGET CODE No. ________ DEP'N RATE ______ %
STANDING ORDER No. ________
FUNCTION CODE ________

YEAR OF COMPLETED COST 19			19			19			19			TOTAL COST			ANNUAL DEPRECIATION			CUMULATIVE DEPRECIATION			DISPOSAL CREDITS			PROFIT (red) OR LOSS ON WRITE OFF			YEAR
£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.	

D



STAFF TYPE
SS ES TA DO RM CW MS AD
GROUP NUMBER
TENS
SF 1 2 4 7
UNITS
SF 1 2 4 7
DATE JOINED COMPANY
TENS
SF 1 2 4 7
UNITS
SF 1 2 4 7
DATE OF BIRTH
UNITS
SF 1 2 4 7
TENS
SF 1 2 4 7
SICK FUND
YES
REFU-SED
DEFER-RED
TURNED DOWN
M.
W.
COST NUMBER
HUNDREDS
SF 1 2 4 7
TENS
SF 1 2 4 7
UNITS
SF 1 2 4 7
ANSON FORM NO. EPC 4222

JONES Harold John
19 Acorn Avenue, London.

DATE of BIRTH - 12.3.1925
DATE ENGAGED - 19.12.1955

SICK FUND..Yes.....Monthly/~~Weekly~~ Paid
TYPE & GROUP No..ES..66..COST No..123....

Design of an edge-punched card used in a personnel record file. Data concerning one employee are typed or written on the card and duplicated by clipping the periphery of the card

Edge-punched cards can be used for all types of commercial work. Two actual commercial applications will be indicated briefly.

A typical use is the maintenance of a personnel record file. A card measuring 4 inches by 5¾ inches is made out for every person employed in the firm. Relevant data about each person are printed in the central portion of the card. Seven items of information are recorded in the hole groups punched round the periphery. These comprise staff type, group number, date of joining company, cost number, monthly or weekly employee, sick fund membership and date of birth.

The system is used for selection. For example, when people are being sought to perform a particular job, it is easy to select the cards of all personnel who fulfil certain requirements. Age distribution of employees of the firm can be easily checked; also, all employees who have completed a certain length of service with the company. Numbers of people contributing to the sick fund can be readily derived and statistics analysing the reasons for refusal. The file of edge-punched cards permits significant data about personnel to be retrieved easily and quickly.

A typical accounting application concerns a schedule of fixed assets. The file contains a card for each asset, whether building or machine. On every card is recorded the initial value of the asset, its annual depreciation and accumulated depreciation. When the asset is written off, the profit or loss is also noted.

Should accountancy statistics be required for any particular type of asset, or group of assets, the appropriate cards can be selected by the techniques already discussed and the values under the various headings totted up on an adding machine. In this way, relevant data are obtained quickly, without the need for an extended manual search of the files.